THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. VIII.

No. V.—MAY, 1911.

With deep regret we record the death of our old and valued friend

PROFESSOR THOMAS RUPERT JONES, F.R.S., F.G.S.,

Editor-in-chief of this Magazine for the first twelve months of its career, 1864–5, who passed away peacefully, after a long and useful life, at "Penbryn", Chesham Bois, Bucks, April 13, 1911, aged 91 years.

He was the author and editor of numerous books and memoirs. From 1850 to 1862, Assistant Secretary to the Geological Society of London, and Editor of the Quarterly Journal.

In 1858 he was appointed Lecturer on Geology at the Royal Military College, Sandhurst, and a resident Professor in 1862; subsequently he served on the Staff College until his retirement in 1880.[1]

ORIGINAL ARTICLES.

I.—CALCITE AS A PRIMARY CONSTITUENT OF IGNEOUS ROCKS.

By RACHEL WORKMAN.

PLATES XI AND XII.

DURING one of the excursions arranged by the International Geological Congress held in Sweden, 1910, we visited, under the leadership of Professor Högbom, a group of islands skirting the shore north of Sundsvall, on the Gulf of Bothnia. Among these islands Alnö and Långörsholmen are of particular interest on account of a complex of alkali igneous rocks forming the whole of the latter and the northern corner of the former. It is to this small but highly interesting group of rocks that I wish to call the attention of the reader, since apart from the short but convincing 'guide' prepared by Professor Högbom (1), scarcely anything has been written on the subject in the English language. The expedition was very skilfully planned, and we were thus enabled to visit several critical exposures and collect numerous specimens for microscopic study.

As one approaches the two islands mentioned above, a marked change in scenery presents itself. The coast of Sweden is protected,

[1] For his life and works see GEOL. MAG., 1893, pp. 1–3 (with a portrait); and op. cit., November, 1909 (Birthday portrait and notice), p. 481. Elected F.G.S. 1852 and F.R.S. in 1872.

as it were, by a fringing archipelago known as the 'skärgard', and the distinctive feature of the numberless lowly islets included in this skärgård is a complete absence of soil and vegetation. Every here and there, bare, smooth, and rounded, granite and gneiss rise out of the sea to a fairly uniform level, beautifully polished and striated—a truly remarkable memorial of the former presence of a great ice-sheet. Only a few Scotch firs have been able to root themselves in cracks and crevices, and except for an occasional coastguard station the solitude is complete. In the midst of this strangely attractive barrenness appears a beautiful fertile oasis, covered with trees, fine meadows, cornfields and prosperous homesteads. It is a merry and hospitable people that has cultivated and developed this little patch, and we have cause gratefully to remember the genial farmers who came forward to welcome us and put at our disposal all the fruits of the earth with the utmost goodwill. They gladly threw open their fields and exposed their property to the searching gaze of the geologist and to the destructive denudation caused by many active hammerers.

One instinctively wonders what produces this remarkable change of scene. It is, in fact, nothing else than the little complex of alkali igneous rocks, responsible for the present paper. The boundary of the oasis is precisely the boundary of this alkali igneous complex, and as one passes outward in all directions on to the surrounding gneiss and granites the landscape again resumes its wonted barrenness.

Primary calcite plays a very important part in the complex under consideration. It is present in all proportions, occasionally forming the main bulk of the rock. Alike in the field and under the microscope it presents all the appearances of a truly igneous constituent. It is found in rocks of every type varying between nepheline-syenite and coarse-grained, banded limestone, in all of them intercrystallized with undecomposed ægirine, nepheline, and other typically igneous minerals. In places, too, it forms calcite pegmatites, showing excellent graphic intergrowth with olivine, mica, and iron ores. It also occurs in fine-grained limestone dykes, cutting both the nepheline-syenite and the coarsely crystalline banded limestones, and bounded by chilled margins against these rocks.

At the edge of the complex where the intrusion comes in contact with the gneiss there are clear indications of marginal assimilation. Quartz appears in the intrusion, no doubt derived from the country rock.

In describing some of the rock-types I will adopt the following order :—

1. The Country Rock.
2. The Plutonic Rocks, including the Massive Limestone.
3. The Dyke Rocks.

1. The Country Rock.

Little need be said of the Country Rock except that it is a coarse, grey, Archæan gneiss, rich in biotite, felspars and quartz. In the neighbourhood of the plutonic intrusion a curious baked variety of

gneiss is found, in which all the minerals are surrounded by reaction rims of alkali felspar; around the biotite this alkali felspar occurs in small grains without definite orientation, but around the old felspar (partly kaolinized orthoclase, oligoclase, and perthite) the new water-clear felspar has consolidated in optical continuity. Owing to extensive interaction between the gneiss and the nepheline-syenite, there is a gradual transition from the one to the other through forms in which the original orthoclase, oligoclase, and perthite of the gneiss have been almost completely changed to newly formed microperthite of orthoclase and albite. Quartz meanwhile takes a subordinate position, and ægirine-augite is developed along with sphene and biotite, the latter showing the habit prevalent in the intrusive mass. It is difficult to say where the altered gneiss ends and the acid border facies of the intrusion begins. For convenience Högbom has drawn the outer limit of the nepheline-syenite at the place where quartz first appears in the rock.

2. The Plutonic Rocks.

The two chief types are nepheline-syenite and an almost pure calcite rock or limestone. There is every gradation between these two, depending on the proportion of the constituent minerals. Certain important basic segregations also occur. There is no regular distribution of the different types, and even within one hand-specimen several varieties may be found. No definite order of crystallization among the minerals is to be observed. Sometimes the femic minerals crystallize before the salic, but often the reverse is the case. Calcite as a rule comes last of all.

The chief minerals are—

Pink orthoclase, which contains a noteworthy amount of barium.

Pink nepheline, sometimes seen in beautiful idiomorphic crystals, standing out on weathered surfaces owing to the solution of enclosing calcite. It is occasionally completely altered into acicular zeolites.

Fresh cancrinite. Its primary character is clearly shown by its mode of occurrence in large plates, into which well-defined crystals of felspar and nepheline project, and in which idiomorphic sphene and pyroxene are scattered; in this mode of occurrence it obviously has not been derived from nepheline. It is also found filling up cracks, and is generally the last mineral to crystallize except calcite. The composition of cancrinite corresponds so closely with the assumption that it is a hydrated compound of nepheline and calcite that its presence in these rocks is just what might be expected. Sometimes it is bordered on one side by nepheline, and on the other by calcite, but at the same time it is rare or absent in the limestones even where nepheline is abundant.

Calcite, very prevalent in almost all varieties of these rocks. It is generally the last mineral to crystallize, and is found in allotriomorphic grains. But it also occurs in well-formed crystals, for Högbom (1) has described a fine-grained nepheline-syenite with porphyritic calcite crystals, partly contaminated by syenite minerals.

Pyroxene, either very slightly pleochroic ægirine-augite or more pleochroic ægirine.

Biotite, sparingly found except in the limestones, in the most basic differentiation products, and in the border acid zones, where it has generally crystallized in ragged flakes later than felspar. Phlogopite is not present except in blocks, not found in situ, seen on Långörsholmen which came from the channel between the latter and Alnö.

Melanite or a titaniferous black garnet, abundant in all types either in zoned rhomdodecahedra or in large irregular crystals, whose outline is determined by the surrounding minerals. The zonal character is roughly shown by the variation in colour from a deep black to a brownish tint. It includes ægirine, calcite, nepheline, and sphene. Thus the crystallization of the melanite extended over a long period, beginning early and finishing late. Just such an occurrence is described (2) (3) in the Borolanite, in Assynt, and in some of its more basic associates, which resemble the Alnö rocks in other particulars.

Sphene, irregularly distributed and sometimes very abundant in fine lozenge-shaped crystals; also twinned and with inclusions of apatite, calcite, and ægirine — in this latter case of comparatively late formation.

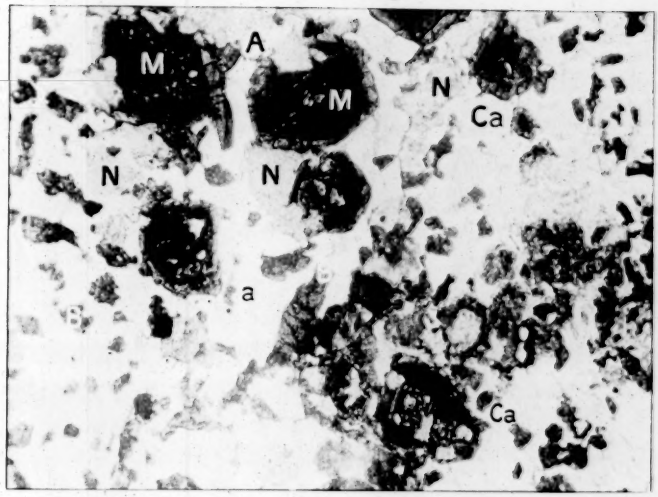
Fluor apatite, free from chlorine, exceedingly abundant. It occurs as grains in the ground-mass and included in the silicates, and also as prismatic crystals arranged in most beautiful stellate rosettes, Pls. XI and XII, Figs. 2 and 3.

Titaniferous magnetite, found mainly in types rich in ferro-magnesian minerals.

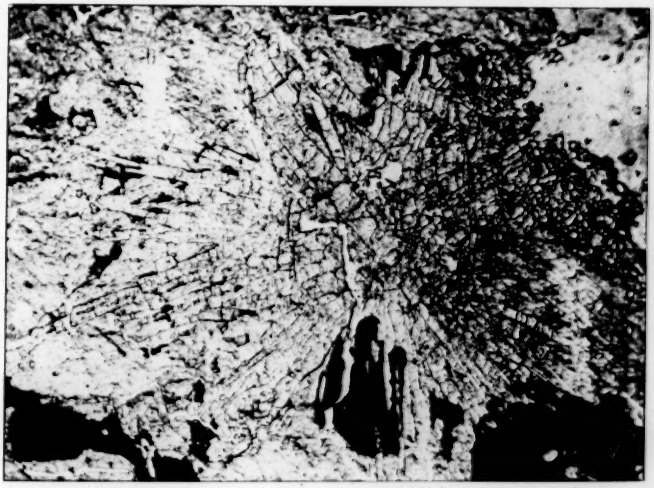
Olivine, confined to the basic and ultra-basic groups and to the limestones. It occurs as fresh crystals, deep black in hand-specimen, and also in all stages of serpentinization.

The nepheline-syenites need no special description here. A typical example is shown in Pl. XI, Fig. 1.

The limestones occur in two modes: either granular, when a distinct banding is seen, or pegmatitic. All the minerals of the nepheline-syenites, except cancrinite, are found in them, and in addition the rarer minerals pyrochlor, knoppite, zircon, and manganophyllite; these latter are found in one locality only. The metamorphic contact minerals such as tremolite, diopside, and forsterite, characteristic of impure sedimentary limestones and dolomites, are always absent. Wollastonite has only been recorded by Törnebohm in an isolated instance, and phlogopite seems to be restricted to the loose blocks mentioned above. Where the limestone is free from normal igneous accessory minerals it is exceedingly pure. Analysis has shown that it then consists of 98 per cent. of calcite. The minerals most commonly associated with calcite, where the latter is abundant, are biotite, apatite, titanomagnetite, olivine, felspar, and ægirine-augite. Of these apatite is the commonest and in parts makes up as much as 20 per cent. of the rock. Its characteristic radial development is seen in Pl. XI, Fig. 2, and Pl. XII, Fig. 3. In granular form it often occurs as numerous inclusions in a framework of nepheline and pyroxene. The structure in the limestones is generally hypidiomorphic, but in the pegmatites very beautiful



1



2

1. Nepheline-syenite. × 120.
2. Radial apatite. × 150.

graphic structure can be seen. The calcite shows clearly in the field, where the nepheline and ferro-magnesians have weathered out from it in ribs. At Långörsholmen near the junction with the typical nepheline-syenite, very large crystals of brown mica two or three inches in diameter are seen graphically intergrown with equally large crystals of calcite. Under the microscope the simultaneous extinction of the mica or the calcite, as the case may be, shows very well that this is an intergrowth of individual crystals. As the structure is on a fairly large scale, it is difficult to get a representative area in the field of the microscope, but Pl. XII, Fig. 3, shows a portion of an intergrowth of this character.

Olivine and calcite are also found in graphic intergrowth. In hand-specimens the calcite then shows a curious schiller lustre, and on careful examination a fine network of greenish-brown substance is seen arranged along its cleavage directions. Under the microscope this proves to be olivine, partly fresh but mostly serpentinized. Plate XII, Fig. 4, shows such an intergrowth with magnetite in addition. The latter is probably part of a single individual crystal; the olivine and calcite certainly are.

Numerous inclusions of nepheline-syenite, two or three inches in diameter up to about one foot, are found in the limestone. These may be either magmatic segregations or else inclusions of nepheline-syenite which have been melted and recrystallized by the limestone in a magmatic condition. Around these inclusions fluidal banding is seen gracefully following the contours of the included syenite. It may be mentioned that the banded limestones of plutonic facies recall in many features the banded gabbros and peridotites of Skye and Rum. In fact, the description given by Sir Archibald Geikie and Dr. Teall (4) of the origin of the banded gabbros of Skye could be applied almost word for word to this case. It seems reasonable, therefore, to regard the banding as a result of flow in a heterogeneous magma. It can scarcely be regarded as a bedding structure, for alternating with layers of almost pure calcite are others consisting of ægirine, ægirine-augite, biotite, nepheline, orthoclase, sphene garnet and titano-magnetite. Black 'schlieren', composed almost entirely of dark constituents, occur every here and there. The minerals interlock across the junctions of the bands, so that these latter cannot be due to successive injections; cataclastic structures have not been observed, and there is no field evidence in favour of dynamic action.

There is, in addition to the nepheline-syenite, limestone and rocks of intermediate composition, a great variety of basic differentiation products consisting mainly of biotite, olivine, titaniferous magnetite, apatite, calcite and a pleochroic augite (violet grey to greenish grey). In places, workable titaniferous magnetite ore is associated with these rocks. These differentiation products are present in quite subordinate amounts, but are of great interest to the petrologist. They may be paralleled with the 'Jacupirangite' and other basic differentiation products of an alkali rock series, in association with the titaniferous magnetite of Brazil described by O. A. Derby (5). The Jacupirangite is, it will be remembered, composed of varying proportions of

titaniferous pyroxene, titano-magnetite, perofskite, and apatite. The basic rock with which the Alnö titaniferous magnetite is associated and into which it passes may therefore be described as a Jacupirangite, sometimes with more apatite than the type-rock, at others with addition of olivine, and always containing calcite.

3. The Dyke Rocks.

These are mainly Alnöites, nepheline-syenite porphyries, tinguaites, nephelinites, and fine-grained limestones. The best known is the melilite basalt described by Törnebohm as Alnöite. It is found in narrow dykes cutting the syenites, limestones, and surrounding gneisses, and it presents a striking difference from most melilite basalts in carrying abundant large crystals of dark mica one or two inches in diameter. Phenocrysts of biotite, titano-magnetite, ægirine-augite, olivine, and apatite lie in a ground-mass of mica, idiomorphic melilite, and calcite. Other primary constituents are perofskite, chromite, garnet, and pyrrhotine. The conditions necessary for the formation of abundant melilite in this rock in preference to nepheline seems to be a high percentage of lime and aluminium with a correspondingly low percentage of silica and alkali.

A fairly common leucocratic differentiation product is a fine-grained tinguaite, which under the microscope shows a ground-mass of beautiful idiomorphic nepheline and tiny felted needles of pale-green ægirine-augite visible with the high power.

Fine-grained limestone dykes of almost pure carbonate, with a small proportion of silicates, are found in many parts, in the nepheline-syenite as well as in the coarsely crystalline limestone. They both cross other dykes, and are crossed by them. They have all the appearance of true igneous intrusions.

Conclusion.

From the evidence which has been outlined above it is abundantly clear that calcite functions as a primary igneous constituent of the Alnö complex.

A few other instances of this phenomenon may now be mentioned in passing. The Alnö conditions are certainly repeated in a most singular manner at Kuolajärvi, in Finland, for Ramsay & Nyholm (10) have described a nepheline-syenite from this locality containing ægirine, cancrinite, nepheline, orthoclase, sphene, and apatite, and, associated with it, another rock containing ægirine, ægirine-augite, biotite, nepheline, apatite, titano-magnetite, calcite, and zeolites. The primary nature of the cancrinite has been established with great care by Sundell (11); as at Alnö this mineral disappears with incoming of abundant calcite.

Again, at Dungannon, in Ontario, Adams (12) has found calcite in a perfectly fresh nepheline-syenite, enclosed in hornblende, nepheline, plagioclase, felspar, and garnet, in such a manner that he is led to regard it as primary. Another example has been recorded by Sir Thomas Holland (13). In describing a group of alkali eruptive rocks on Sivamalai, in the Charnockite Series, Madras, he says: "The principal feature of interest is connected with the

presence of calcite in granular crystals, with apparently as much right, as any of the others, to be considered as a primary constituent. The crystals form isolated granules, and there is apparently no sign of secondary decomposition, or structures which suggest its infiltration into the rock."

More numerous instances might be cited to illustrate the occurrence of primary cancrinite in nepheline-syenites and allied rocks, but this would lead too far afield.

As a rule, in dealing with minerals which have crystallized to form igneous rocks, one does not inquire further into their history after ascertaining their primary nature. But in the case of calcite an exception may be made: this mineral is, in the great majority of cases, formed and concentrated under obviously non-magmatic conditions; and accordingly the question arises, has the Alnö magma incorporated a sedimentary limestone mass?

A very limited example of such incorporation has been demonstrated by Dr. Teall (6, pp. 456, 460), at the contact of the Borolan syenitic complex with the Durness dolomite. At one point a mixed rock has been found, consisting of orthoclase, calcite and ægirine-augite, the latter grown about crystals of diopside which has resulted from the contact alteration of the impure dolomite. Absorption has also been suggested by Daly (7) (8) to account for the presence of the calcite of the Dungannon syenite, and this is not unreasonable, since the latter occurs in close association with sedimentary limestones.

From these cases, and from the well-marked stability of calcite in pure limestones subjected to contact metamorphism, it is clear that an alkali-syenite magma, in which the silica present is thoroughly saturated with bases, may quite well absorb calcite without leading to the dissociation of the mineral. But a sub-alkali magma may be expected to react with any calcite which came to be incorporated, liberating carbon dioxide, and at the same time yielding silicates rich in calcium; such reactions would, of course, only proceed until the magma had been desilicated to a sufficient extent to render any further calcite absorbed immune from attack. It is quite conceivable, for instance, that through the withdrawal of silica in combination with lime, a normal granitic magma might eventually be converted into a variety of felspathoid syenite. From considerations of this character, combined with Lœwinson-Lessing's views (9) that sometimes the assimilation of a small quantity of foreign matter in a magma is sufficient to induce differentiation to a greater or less extent, Daly has been led to regard alkaline rocks in general as derived from sub-alkali magmas through the absorption of limestone, followed by induced differentiation. This view he supports by calling attention to the small relative bulk of alkali-magmas, and to the suggestive association of the latter in several cases with limestones, under circumstances which admit of the possibility of important absorption. For Daly, Alnö and Finland offer clear evidence, not merely of the absorption of limestone, but also of the consequent evolution of alkali magmas.

In applying this line of argument to Alnö, however, the question arises, where did such a limestone as is postulated on the absorption

theory come from? Högbom is uncertain as to the age of the complex, which he considers probably pre-Cambrian, but possibly Devonian, so that it is conceivable that limestone may have been derived either from the Archæan, or, as a result of 'stoping', from overlying 'orthoceras kalk', which latter has now been entirely swept away by erosion from the surrounding country. But no limestones are known in the Archæan of this region, and the 'orthoceras kalk' is very impure, whereas the Alnö limestone, apart from normal igneous minerals (as opposed to contact minerals), is exceptionally free from contamination.

Högbom's conclusion is, that the calcite has crystallized from the magma in a manner exactly analogous to the other minerals. He suggests that the syenites and limestones may have been separated during the general differentiation of which there is so much evidence among the dyke-rocks of Alnö. But the two cases are not exactly analogous, for the various dyke-rocks present differ from one another in regard to the nature of the minerals, while the syenites and limestones are distinguished by their quantitative but not by their qualitative mineralogical constitution. It is important to notice that the minerals in these plutonic rocks have not concentrated in a definite order; as far as I have been able to judge no definite law for the order of crystallization can be given here. Therefore there is no differentiation due to a regular order of crystallization.

But we shall not digress further into the interesting questions raised by the presence of primary calcite in the igneous complex of Alnö. The main purpose of this paper has been fully attained if it has enabled the reader to form some conception of the unwonted experiences and pleasant surprises which awaited us in this out of the way island, whither we were led by Professor Högbom.

References to Literature.

(1) Högbom, A. G., "Ueber des Nephelinsyenitgebiet auf der Insel Alnö": Sveriges Geologiska Undersökn, ser. C, 1895. "The Igneous Rocks of Ragunda, Alnö, Rödö, and Nordingrå": Geol. Fören. Förhandl., 1909.

(2) Horne, J., & Teall, J. J. H., "On Borolanite": Trans. Roy. Soc. Edinb., vol. xxxvii, pt. i, 1892.

(3) Shand, S. J., "On Borolanite and its Associates in Assynt": Trans. Edinb. Geol. Soc., vol. ix, pt. v, 1910.

(4) Geikie, A., & Teall, J. J. H., "On the Banded Structure of some Tertiary Gabbros in the Isle of Skye": Q.J.G.S., 1894.

(5) Derby, O. A., "On the Magnetite Ore District of Jacupiranga, Brazil": Amer. Jour. Sci., 1891.

(6) Teall, J. J. H., in "The Geological Structure of the North-West Highlands of Scotland": Mem. Geol. Surv., 1907.

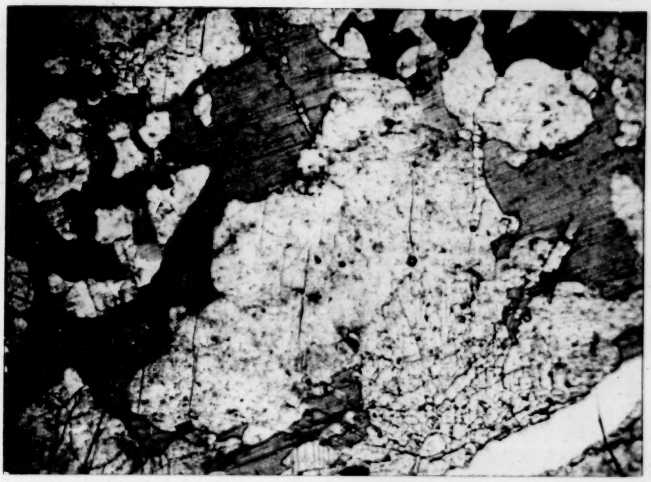
(7) Daly, R. A., "The Mechanics of Igneous Intrusion": Amer. Jour. Sci., vol. xxvi, 1908.

(8) ——— "Origin of the Alkaline Rocks": Bull. Geol. Soc. Amer., vol. xxi, 1910.

(9) Lewinson-Lessing, F., Compte Rendu Seventh Internat. Geol. Congress, St. Petersburg, 1897.

(10) Ramsay, W., & Nyholm, F., "Canerinite Syenite, Kuolajärvi": Bull. Comm. Geol. Finlande, 1895.

(11) Sundell, J. G., ibid., 1905.



3

4

3. Graphic intergrowth: Mica and Calcite. × 90.
4. Graphic intergrowth: Calcite with Olivine and Magnetite. × 90.

(12) Adams, F. D., "The Nepheline Syenite of Dungannon, Ontario": Amer. Jour. Sci., 1894.
(13) Holland, Sir Thomas, in Mem. Geol. Surv. India, vol. xxx, 1901.

EXPLANATION OF PLATES XI AND XII.

Plate XI.

Fig. 1. Nepheline-syenite [×120] showing general structure. M. melanite garnet; N. nepheline; B. ægirine; A. apatite; Ca. calcite.
,, 2. Radial apatite [×150].

Plate XII.

,, 3. [×90.] Graphic intergrowth of mica and calcite—radial apatite in upper portion.
,, 4. [×90.] Graphic intergrowth of calcite with olivine and magnetite.

II.—Note on the Limestone Fragments in the Agglomerate of the "Rock and Spindle" Volcanic Vent, St. Andrews, Fife.

By David Balsillie, St. Andrews.

In the agglomerate of the volcanic necks of Eastern Fifeshire are incorporated, as has long been known, numerous fragments of sedimentary rock. These, it is generally believed, represent the broken-up remains of the strata which at some former time occupied their sites. Many of them have obviously been subjected to excessively high temperatures, others show no sign whatever of igneous action. Thus, occasionally we find quartzites and lydian stone representing what once must have been sandstones and clay shale; or, again, the constituent layers of a sandy or carbonaceous shale may be seen to be still adherent and so little altered as to display on a freshly exposed surface admirably preserved plant-remains. Limestone blocks also occur sometimes converted into marble, frequently unchanged; in the latter case, exhibiting on their weathered exteriors the remains of those organisms which give at once the clue to the conditions accompanying the deposition of their parent stratum. It is with special reference to these limestone fragments that this note has been written and particularly to those occurring in one vent—the well-known "Rock and Spindle"—a mile and a half to the east of St. Andrews.

To be quite brief, the "Rock and Spindle" volcanic vent can now be seen to penetrate a portion of that group of Lower Carboniferous sediments which in Central Scotland is known as the Calciferous Sandstones. Intercalated among the strata through which it has risen is one well-known limestone band, the Encrinite-bed. Numerous fragments of this calcareous stratum are, of course, to be found in the agglomerate just as we should expect. In addition to these, however—and the fact does not seem to have been formerly emphasized—are frequent pieces of a white limestone which in the immediate neighbourhood has no counterpart. From these last-mentioned fragments I have at one time or another obtained the following fossils. Most of them were collected in the north-western portion of the vent, and especially did they occur in the decomposed blocks above high-water mark.

Lithostrotion irregulare, Phill.
L. junceum, Flem.
Zaphrentis sp.
Crinoid ossicles (many large).
Echinoid spines and plates.
Batostomella sp.
Rhabdomeson rhombiferum, Phill.
Athyris ambigua, Sow.
Orthis resupinata, Mart.
Productus semireticulatus, Mart., var.
Productus, several species indet.
Productus spines.
Rhynchonella pleurodon, Phill.
Aviculopecten sp.
Nucula gibbosa, Flem.
Nuculana attenuata, Flem.
Bellerophon Urei, Flem.
B. decussatus, Flem.
Loxonema sp.
Macrochilina sp. (*imbricata?*), Sow.
Pleurotomaria sp.
Orthoceras sp.

About this assemblage of fossils there is something that is here peculiar. Suppose I were requested to collect such a suite from the stratified rocks of North-Eastern Fife I should certainly not go to any portion of the Calciferous Sandstones (the strata through which the agglomerate can be seen to rise), but to some of the well-marked marine horizons in the lower portion (Lower Limestones) of the next overlying group of sediments, the Carboniferous Limestones. It would, of course, be natural to expect that the fragments which furnished the foregoing list of fossils must have been derived from some calcareous stratum underlying this precise portion of the coast-line anterior to the volcanic outburst. As has been said, however, the only known limestone at this part is the Encrinite-bed, but from that horizon the following species have not so far been obtained—*Lithostrotion irregulare*, *Zaphrentis*, and *Orthis resupinata*. In addition to this the mode of occurrence of the corals is quite different from that in the Encrinite-bed. Blocks are found entirely made up of the cylindrical corallites of *Lithostrotion*, and are just such as we should expect to have been derived from some of the Lower Limestones. Again, the size of the blocks renders an Encrinite-bed parentage improbable; one at the upper part of the beach was found to measure $20 \times 14 \times 12$ inches, and the Encrinite-bed in the near vicinity is only some 5 inches thick.

Having therefore established the fact that these limestone fragments belong to a higher stratigraphical horizon than any through which the vent can now be seen to rise, how can their presence here be accounted for? The most probable explanation appears to be that some at least of the Lower Limestones formerly overspread this portion of the county, and were actually penetrated by the vent. The disrupted fragments were enclosed in the agglomerate which subsequently subsided within the orifice, while the overlying and surrounding sedimentary rocks have been entirely swept away.

III.—On some British Pillow-lavas and the Rocks associated with them.

By Henry Dewey and John Smith Flett.

(By permission of the Director of H.M. Geological Survey.)

THE pillow-lavas are a group of basic igneous rocks that occur, in our experience, only as submarine flows, and very frequently exhibit 'pillow-structure'. A lava-flow of this type is composed of

sack-shaped masses, globular or elongated, and varying in size. The external surface of the pillows may be compact, but in their interior there are numerous cavities often concentrically arranged. First described in Britain by Nicholas Whitley (1), and figured also by De la Beche (2), they have become generally known through the work of Teall (3), Raisin (4), Reid and Dewey (5), and their importance among the Palæozoic eruptive rocks of Britain is now well established.

Although pillow-structure is rarely completely absent, it may not be well exhibited in every exposure of these rocks, especially when, as in Cornwall and Devon, they have been exposed to earth-movements and folding. On the other hand, pillow-structure may make its appearance in rocks that do not strictly belong to this group. Thus it is sometimes seen in the Carboniferous basalts of the Lothians and Fife (6), though not well developed.

The name spilites was given to rocks of this class by Brongniart (7) in 1827, and has recently, in accordance with the usage of Continental petrographers, been adopted by the Geological Survey to designate the Carboniferous, Devonian, and Ordovician pillow-lavas of Devon and Cornwall. It was first used in English by Bonney (8) for certain rocks in Jersey that seem to be properly included in this group.

In addition to the pillow-structure there are certain characteristics that mark the spilites of Great Britain. The first of these is that they are as a rule very completely decomposed, and the second that their felspars are always rich in soda. Their micro-structure varies within rather narrow limits. The principal component is felspar; next in importance is augite of pale-brown colour; remains of olivine are sometimes, though not often, to be detected. Frequently they seem to have contained a fair amount of glassy base, though this is always devitrified and decomposed. Their felspars are occasionally micro-porphyritic, and often those of the ground-mass have pointed or acicular forms. A few British spilites have large felspar phenocrysts. Sometimes they consist almost wholly of felspar laths with a fluidal arrangement. A large number of spilites are variolitic, and in these the augite may occur as irregular masses enclosing the ends of felspar rods, so that the structure may be described as sub-ophitic.

The advanced decomposition exhibited by the vast majority of these rocks has led to their being classed as 'diabase-porphyrites'; and when they are sheared they form typical 'schalsteins'. We find these characters not only in the pre-Cambrian and Ordovician spilites. In Cornwall the Devonian and Carboniferous spilites and schalsteins never contain olivine or augite, but their ferro-magnesian minerals are completely replaced by secondary products (chlorite, calcite, and epidote).

The felspar is sometimes decomposed beyond identification. Dr. Teall (9) was the first to determine its real nature in the pillow-lavas of the Southern Uplands of Scotland. He recognized it as oligoclase, and confirmed this identification by chemical analyses. We have examined hundreds of sections of spilites from Cornwall and Devon, and have found that the only felspar they contain is albite or albite-oligoclase.

There are two ready tests by which this felspar can be recognized. It has all indices of refraction lower than that of Canada balsam,

which in the slides made for the Geological Survey has very closely the refractive index of the ordinary ray of quartz (1·544), and in convergent light it has positive optical sign. These tests exclude all felspars more rich in lime than oligoclase-albite, and are better than any methods depending on extinction angles. The only difficulty in applying them is that the felspar is often filled with minute grains of chlorite and epidote. We shall see that chemical analyses have in several cases placed the identity of the felspar beyond question.

The albite is sometimes very clear and transparent, suspiciously so when we remember the highly decomposed state of the rocks in which it occurs. At other times it has a milky translucency, while in many rocks it is filled with infinitesimal grains of chlorite or epidote. Hence there is reason to believe that in some degree the soda-felspar may be secondary, and that possibly the rocks have been albitized. Now albitization, or the replacement of other felspars by albite, takes place in many ways, as might be expected in a phenomenon so generally displayed by the older igneous rocks. Apparently it is sometimes a result of ordinary processes of weathering by which albite and calcite or epidote replace lime-soda plagioclase. Among the best instances of this type the rocks of Bardon Hill in Charnwood Forest may be adduced. Their felspars were zonal with basic centres, and the interior of the crystals is now a meshwork of albite enclosing many grains of epidote, while the margins are nearly solid albite. Albite and epidote or zoisite may also arise from lime-soda felspar through shearing, as in many of the amphibolites derived by movement from the basic intrusive rocks of the North-East Highlands of Scotland. But albite also replaces lime-soda felspar by a process of albitization, as Bailey and Grabham (10) have shown, which may be a juvenile, post-volcanic, or pneumatolytic mode of alteration.

In the Cornish pillow-lavas the felspars occur in several distinct states. They may be entirely replaced by calcite, quartz, and sericite, as in many lavas of Brentor. In other rocks the lath-shaped sections of felspar are a network of albite with the interstices occupied by secondary minerals such as chlorite and calcite. We can hardly avoid the suspicion that what lime felspar was originally present has been dissolved out, as in the rocks described by Termier (11) and the gaps filled in with decomposition products. But in a fair number of the rocks of this class the albite is clear and fresh, by no means very full of inclusions, and has much of the appearance of a primary mineral. Yet all the other components of these spilites have been completely decomposed; no augite can be found in them, and the matrix is a dense aggregation of secondary products. An example of this class is furnished by the lava of Devonport Workhouse near Plymouth (12). Its albite crystals are not zonal except that their interior is rather spongy and full of secondary inclusions, while their external portions are compact.

In rocks of this type it must be conceded that albitization of soda-lime felspar has occurred on a not inconsiderable scale. We believe that this is to be ascribed to a pneumatolytic change that affected the spilites very shortly after their effusion. It

must be remembered these are only the westward prolongation of a great series of pillow-lavas (13) (with attendant keratophyres, minverites, etc.) that extend from Moravia through Nassau across the Rhine into England. Many accounts of these Devonian schalsteins have been furnished by Continental petrographers. Some have noticed their richness in soda, but other felspars are often described as characterizing this group of rocks. Many of them contain fresh augite and labradorite or andesine, in others the felspar is partly oligoclase. The Devonian spilites of the West of England contain no pyroxene and no felspar but albite. Yet there can be no doubt that they are the effusive rocks of one eruptive period, furnishing one of the best examples of a petrographical province that could be adduced. Hence, as the most decomposed rocks contain most albite it seems reasonable to assume that the mineral is in some way of secondary origin.

In these rocks albite occurs sometimes in vesicles and veins, but the minerals of the amygdules are mostly calcite, chlorite, and quartz. The highest lavas of the series are interbedded in the Lower Carboniferous. At the close of the Carboniferous period the Armorican earth-movements began. The spilites were crushed and, when highly vesicular, were torn in shreds. Their felspars are broken and twisted, and the evidence of the slides proves that before the movements set in the albitization and decomposition were complete, for the broken albites are not healed or their fractured surfaces united by new deposit.

Shortly after the movements ceased (perhaps before they were completely at an end) great eruptive granites, of which the Dartmoor mass is the best known, invaded the region. The lavas were at that time rotten and sheared, and their vesicles filled with secondary minerals. Within the aureoles of the granite bosses they were now hornfelsed and their albite felspar replaced by andesine and labradorite, while their calcite and chlorite gave rise to epidote, augite, biotite, and hornblende. The basic felspar can be traced in every stage of development as we follow the spilitic lavas from the outer precincts of the aureoles to the actual contacts with the granite; and that the felspar is recrystallized from a mineral that was full of secondary products can be proved by the abundance in it of specks of hornblende, augite, and biotite, that gradually coalesce to larger grains as the alteration becomes more intense. The new basic felspar produced in this way in late Carboniferous times is still perfectly fresh and clear; this proves that some factor other than mere lapse of time with concomitant weathering must be regarded as the prime agency of albitization in this case.

To show the chemical composition of these rocks we quote some analyses that have been prepared in the laboratory of the Geological Survey. These demonstrate clearly the essential characters of the group: they are basic rocks much decomposed and rich in carbonates and combined water. In all cases the soda is high for basic rocks, while the potash is very low. If the carbonic acid of the first, second, and third analyses is assumed to be combined with lime to form calcite, an assumption that has been verified by chemical tests, the amount of lime felspar present must be quite negligible.

ANALYSES OF BRITISH SPILITES.

	I.	II.	III.	IV.
SiO_2	51·31	46·4	47·56	40·55
TiO_2	1·92	·24	2·40	2·95
Al_2O_3	12·67	20·4	14·27	16·65
Fe_2O_3	·54	6·9	1·63	1·13
FeO	7·99		6·80	9·46
MnO	·45	—	·30	·20
(Co Ni) O	?trace	—	·08	·07
BaO	nt. fd.	—	nt. fd.	nt. fd.[1]
CaO	8·17	7·7	10·95	6·06
MgO	2·19	3·5	4·90	5·20
K_2O	·54	·54	·27	·27
Na_2O	5·21	6·93	4·61	4·76
Li_2O	?trace	—	?trace	?trace
H_2O (at 105° C.)	·04	—	·42	·27
H_2O (above 105° C.)	2·31	1·1	2·65	3·89
P_2O_5	·90	—	·19	·73
FeS_2	·30	—	·22	—
S	—	—	—	·10
Fe_7S_8	·17	—	·05	—
CO_2	6·15	5·8	2·95	7·85
	100·86	99·51	100·25	100·14

I. West side of Tayvallich Peninsula, Argyllshire (analysed by E. G. Radley, S. 12453).

II. Gatelochside Burn, near New Cumnock, Ayrshire (analysed by J. J. H. Teall). "The Silurian Rocks of Britain"; vol. i, Scotland: Mem. Geol. Surv., 1899, p. 85.

III. Tregedden, South Cornwall (analysed by E. G. Radley, E. 5791).

IV. Devonport Workhouse Quarry (analysed by W. Pollard). "The Geology of the Country around Plymouth and Liskeard": Mem. Geol. Surv., 1907, p. 97.

The Albite-diabases.

With the spilites both in Europe and America, diabases invariably occur, representing the intrusive magma that consolidated below the surface. Some of them contained olivine, but their characteristic minerals are purplish augite (of various shades), plagioclase felspar, and titaniferous iron-ores. Like the spilites they are rarely fresh: their olivine is always decomposed and their augite is frequently replaced by chlorite, epidote, and calcite, though it is far more commonly in good preservation than the pyroxene of the spilites. The only felspar in the vast majority of these rocks is albite, and it is often present in surprising quantity. That basic plagioclase originally formed the inner zones of many felspar crystals may be assumed from the frequency with which the albite has a spongy centre filled with epidote, prehnite, and chlorite, while the margins are compact. But in these diabases veins and segregations occur that are of paler colour and especially rich in soda-felspar, in fact they are almost pure albite rocks. Instances may be cited from Newlyn Quarry, Cornwall (14), and Trusham in Devon, and similar rocks have been described from Germany by Brauns (15). On analysis many of the

[1] A substance is reported as not found (nt. fd.) when, though searched for in the usual way, no traces of it have been obtained by the analyst.

diabases differ but little from ordinary diabases except in the slightly higher percentage of soda that they contain. Others, however, contain as much as 5 per cent. of soda, an unusual amount for rocks of this type. There can be no doubt that they are a basic group characterized by abundant alkalies and hence possessing affinities with essexite, as has been recognized by Flett (16), Ehrmannsdorfer (17), and Weber (18).

It is equally certain that in some cases they have been albitized and have had additional soda-felspar introduced after they had consolidated. An example occurs in the Kit Hill diabase (19). It has large rectangular felspars with interstitial anidiomorphic augite and iron-ores. The two last-named minerals are rather decomposed, but the felspar is very fresh, clear, and homogeneous. It occurs in fairly large crystals which are not zoned, and it has the optical properties of albite. By means of bromoform it was separated from the crushed powder of the rock, and analyses confirmed the optical tests by showing that it was almost chemically pure albite.

In Cornwall and Devon the albite-diabases, like the spilites, were completely decomposed and albitized before the late Carboniferous earth-movements, and were hornfelsed by the granites. Their soda-felspar was then replaced by andesine and labradorite, which is still in excellent preservation. Here again it is certain that the albitization ensued very soon after the rocks were intruded, and we infer that it was of pneumatolytic character.

Minverites (Proterobases).

Certain rocks from North and East Cornwall that were described by Teall (20) as hornblendic diabases were subsequently described by Flett (21) as proterobases. In 1910 Dewey (22) proposed the name minverite for similar rocks from St. Minver, North Cornwall. They are much like the diabases, but contain fresh brown primary hornblende. Sometimes traces of olivine (never fresh) occur in them; they are not usually ophitic, and contain much brown and purplish augite. Primary alkali-felspar, mostly albite, is often abundant in the minverites. Analyses of these rocks from Cartuther and St. Mabyn show that they are of the sub-alkalic group of basic rocks, very close in many respects to the essexites. Often they contained a limited amount of lime-soda felspar, now replaced by albite, epidote, and prehnite, or in some cases almost wholly albitized. Other features of this group are the striking abundance of apatite in long thin prisms, and the occasional presence of deep-brown biotite. At Polyphant they are closely associated with the hornblende picrites.

Quartz-diabases.

Here and there in Cornwall quartz-diabases (23) occur among the spilites and albite-diabases, and belong to the same volcanic epoch. Yet in these rocks the basic felspars remain, every zone is perfectly distinct, the most basic in the interior, the most acid externally. Clearly, then, the albitization is a process intimately connected with the nature of the individual rock; the spilites and quartz-free diabases show it, but the quartz-diabases do not. We are reminded of the manner in which some granites are attended by pneumatolytic phenomena

(formation of greisen, etc.) while others are practically free from them. Bailey & Grabham (24) showed that the quartz-diabases of Scotland are occasionally albitized, but only locally and incompletely.

Picrites.

Several picrites have been recorded from Cornwall and Devon, mostly hornblende picrites. Similar rocks occur in the Devonian of the Rhine. They contain a little felspar, usually labradorite or bytownite, and, as in the quartz-diabases, it is not albitized.

ANALYSES OF ALBITE-DIABASES, MINVERITE, AND PICRITE.

	I.	II.	III.	IV.
SiO_2	59·84	46·73	47·19	39·14
TiO_2	·64	2·74	2·09	1·66
Al_2O_3	15·71	18·73	13·96	7·59
Fe_2O_3	1·68	nt. fd.	3·39	5·26
FeO	7·03	10·14	9·01	8·76
MnO	·12	·37	·47	·56
(Co Ni) O	—	—	·04	·11
CaO	3·71	8·62	8·08	5·91
MgO	1·37	3·56	7·10	22·78
BaO	—	—	·06	nt. fd.
K_2O	2·76	·88	·70	1·09
Na_2O	6·52	3·54	4·50	·60
S	·10	—	—	—
FeS_2	—	·05	·11	—
CO_2	—	·58	·79	—
P_2O_5	·20	·37	·56	·38
H_2O (at 105° C.)	·14	·35	·12	·56
H_2O (above 105° C.)	·31	3·31	2·56	6·30
	100·13	99·97	100·73	100·70

I. Gwavas Quarry, Newlyn, Cornwall (analysed by W. Pollard). "The Geology of the Land's End District": Mem. Geol. Surv., 1907, p. 35.

II. Albite-diabase, Trusham Station Quarry, west side of Teign, Devon (analysed by E. G. Radley, E. 6808).

III. Proterobase, 200 yards north of viaduct, south-west of Cartuther, Cornwall (analysed by W. Pollard). "The Geology of the Country around Plymouth and Liskeard": Mem. Geol. Surv., 1907, p. 100.

IV. Hornblende picrite, Criffle Mill, Molenick, Cornwall (analysed by E. G. Radley). Ibid., p. 101.

The rocks that we have considered are of basic or ultra-basic composition, but acid and intermediate rocks also accompany the pillow-lavas. Of these we may distinguish the keratophyres (and albite-trachytes), quartz-keratophyres (and soda-felsites), and the soda-granites.

Keratophyres, etc.

The keratophyres are typically quartz-free. They consist of albite, chlorite, and iron-ores, and the structure varies from orthophyric to porphyritic; the phenocrysts are anorthoclase or albite. First described by Teall from the Southern Uplands of Scotland (25), and subsequently from Mevagissey in Cornwall (26), they have been found also in association with the pillow-lavas of Tavvallich (27), and the variolites of Fishguard (28). Quartz-keratophyres contain usually phenocrysts of corroded quartz and albite or anorthoclase, in a matrix that may be felsitic or microcrystalline. The soda-felsites are often strikingly perlitic. Quartz-keratophyres are common in Devon with

the pillow-lavas there, and soda-felsites occur in the Southern Uplands of Scotland.

Soda-granites.

The soda-granites are coarse-grained rocks, generally with phenocrysts of albite. The matrix is a holocrystalline mixture of quartz and albite. Ferromagnesian minerals are rare, but include biotite and pyroxene, the latter represented only by pseudomorphs. Rocks of this class occur at Porthallow in South Cornwall, where they are intrusive in the Ordovician pillow-lavas; and at Tayvallich in Argyllshire they penetrate the spilites that are interbedded with the limestones and schists of the Central Highland metamorphic series.

ANALYSES OF KERATOPHYRES, SODA-FELSITES, ETC.

	I.	II.	III.	IV.	V.
SiO_2	64·38	66·05	79·64	72·51	65·67
TiO_2	—	·49	·50	·31	·19
Al_2O_3	16·98	13·29	11·44	13·10	13·72
Fe_2O_3	4·04	3·22	·11	2·81	·50
FeO	—	5·07	·30	·90	1·17
MnO	—	—	·08	·20	·13
CaO	1·08	·50	·71	1·84	3·21
(Co Ni) O	—	—	—	—	·02
BaO	—	—	—	—	·04
MgO	·28	1·36	·15	·20	1·52
Na_2O	7·57	6·67	6·40	6·76	6·26
K_2O	4·30	·87	·38	·33	1·68
Loss on ignition	1·64	1·88	·30	·35	·84
H_2O (at 105° C.)	—	·96	·16	·04	·28
P_2O_5	—	·09	·08	·06	·09
CO_2	—	—	·02	·76	4·86
FeS_2	—	—	—	—	·03
	100·27	100·45	100·27	100·17	100·21

I. Keratophyre, Hamilton Hill (analysed by J. J. H. Teall). "The Silurian Rocks of Scotland": Mem. Geol. Surv., 1899, pp. 88–9.

II. Keratophyre, Trevennen (analysed by W. Pollard). "The Geology of the Country around Mevagissey": Mem. Geol. Surv., 1907, p. 56.

III. Soda-rhyolite, west side of Skomer Island, top of cliff west of the spit (analysed by E. G. Radley, E. 7768).

IV. Soda-granite, Tayvallich, Argyllshire (analysed by E. G. Radley, S. 13221).

V. Soda-granite, north corner of Porthallow Cove, Cornwall (analysed by E. G. Radley, E. 6377).

We have, then, a long and varied suite of igneous rocks belonging to the spilite association. The commonest are always spilite and diabase; next in abundance are keratophyres and quartz-keratophyres; less frequently we find soda-granite, minverite, and picrite. They range from ultra-basic rocks like picrite to highly acid quartz-keratophyres, and their chief characteristic is the abundance of soda, even in the basic types. A close parallel can be drawn between them and the picrites (teschenites), dolerites and basalts, trachytes, and rhyolites of the Carboniferous rocks of Scotland (29). In both series felspar-free rocks occur (picrites and peridotites) and quartz-diabases, otherwise the spilite suite is always the richer in soda, and shows an additional characteristic, the almost universal and often complete albitization of the lime-soda felspars.

(To be concluded in our next Number.)

IV.—A New Pleistocene Fauna from Tokyo, with a General Statement on the Pleistocene Deposits of Tokyo, Japan.

By Dr. H. Yabe, Geological Institute, University, Tokyo, Japan.

JUST before my departure from Tokyo to Europe, in 1908, my attention was called, by the kindness of Mr. Gordon Yamakawa, to a fossil fauna from a cutting along the Yamanote line of the circum-Tokyo railway, near the Tabata station. It was seven years ago, when the railway line was still in process of construction, that Mr. Yamakawa formed a collection of fossils, consisting exclusively of molluscan remains. Of special interest is the abundant occurrence of *Tellina venulosa*, Schrenk, in the shell-sand, and as its presence is really of exceptional interest in the environs of Tokyo we visited the place together soon afterwards. The present brief account is contributed partly for the purpose of recording the observations of this diligent young student of fossils, whose lamentable and too early death took place last autumn, during my absence in Europe, and partly with the intention of interesting others in the further study of the Pleistocene and Pliocene geology of Tokyo, which though apparently quite simple, contains many interesting and unsettled geological questions.

The surface of Tokyo is topographically divisible into two parts: higher terrace-land and lower alluvial plain, as very well expressed by our plain terms *Takadai* and *Shitamachi*. The change from the first to the second is usually abrupt, with the average difference of 15 metres in height, and marked by a series of nearly vertical bluffs; for instance, the ridge connecting Ueno and Asukayama is merely the vertically cut end of the terrace land, which trends S.E.–N.W., and faces N.E. Along the very foot of the ridge lies the Owu line of railway; the above-mentioned Tabata station is situated about two miles N.W. of Ueno, and there the Yamanote line branches out from the Owu line and enters into a cutting through the terrace land. The fossil locality visited by us is situated just in the entrance to this cutting.

The greater part of the cutting, about 12 metres in height, was already grass-covered, but evidently consisted of loam and the underlying thick sandy gravel bed. The latter was succeeded by a bed of brownish sand, about one-third of a metre thick, which is very variable in character and liable in a short distance to pass into an argillaceous sand or an arenaceous clay. The remaining lower part of the cutting, about 2 metres in thickness, was already to our great regret enclosed by a stone wall, just at the spot where Mr. Yamakawa had made his collection of fossils; at a little distance from the spot, however, we could actually examine brownish arenaceous clay, full of vertical pipes, exhibited on the same level as that of the recently exposed and now hidden shell-sand. This arenaceous clay passes gradually upward to the above-mentioned brownish sand; no marked stratigraphical boundary is recognizable between these. That the distribution of the shell-sand was confined to a very limited area was also obvious from the present widely scattered remains of the once excavated fossil shells over the floor of the cutting, and also in an open drain.

Only 200 metres or a little more distant from the place are two,

long abandoned, great sand-ditches along the Owu line, where very prolific shell-beds were once exposed. The detailed account of these fossiliferous beds and their contained fossils are given by Mr. S. Tokunaga[1] in his work "Fossils from the Environs of Tokyo", 1906, from which the following lines are quoted for the sake of comparison :—

"The brownish and bluish clay layers at the bottom of my profile [which on p. 93 shows the downward succession of loam 5·78 metres, clay 0·6 metre, gravel 6·0 metres, and brownish and bluish clay] contain different kinds of fossils at different parts even of the same horizon. In some parts we find numerous plant-leaves, while in others trunks of trees and shells. Where the shells are numerous, the clay passes into sands. . . . Below the clays is found a bluish sand which yields some molluscan casts at Shinagawa and Oji, and numerous shells at Tabata. At the last locality no bed lower than this sand is exposed. But at Shinagawa and Oji there is a sand with numerous shells, showing a wavy line of boundary against the overlying sand on natural profiles."

It may be here remarked that the boundary question of Diluvium and Pliocene was much discussed by D. Brauns, T. Suzuki, Tokunaga, and others, in reference to this wavy line above the principal shell-bed of Oji. A similar and even sharper wavy line is seen between the sandy gravel bed and the underlying brown clay at Tabata; at the end of this paper the question will be shortly referred to.

MOLLUSCA, ETC., FROM THE SHELL-BEARING SANDS AND OVERLYING ARGILLACEOUS BED OF TABATA.

MOLLUSCA.

GASTEROPODA.

Rapana bezoar, L.
Nassa japonica, A. Ad.
N. livescens, Phil.
Columbella martensi, Lischke.
C. pumila, Dkr.
Drillia tabatensis, Tok.
Natica ampla, Rve.
Scalaria lamellosa, Lam.
Eulima ovalis, Tok.
Pyramidella spirata, A. Ad.
P. cinctella, A. Ad.
Cerithium nipponiensis, Tok.
Cerithiopsis tabatensis, Tok.
Lampania zonale, Brüg.
Potamides fluviatilis, Potiez & Mich.
Rissoa (*Fenella*) cf. *cerithina*, Phil.
R. septentrionalis, Tok.
R. subcylindrica, Tok.
Rotella costata, Lesson, var. *superbus*, Gld.
Turbo granulatus, Gmel.
Acmæa conulus, Dkr.
Patella (*Heliconiscus*) *amussiata*, Reeve.
Tornatina exilis, Dkr.
Ringicula arctata, Gld.
Cylichna musashiensis, Tok.
Bulimella obtusa, Tok.

LAMELLIBRANCHIA (or PELECYPODA).

Martesia striata, L.
Solen krusensterni, Schrenk.
Saxicava arctica, Desh.
Tellina jedoensis, Lischke.
T. serricostata, Tok.
Macoma nasuta, Conrad.
Cyclina chinensis, Chem.
Tapes decussata, Dkr., var. *philippinarum*, Ad. & Rve.
Lasæa striata, Tok.
Arca inflata, Rve.
A. tenuis, Tok.
A. granosa, L.
Modiola modiolus, L.
Anomia aff. *patelliformis*, L.
Ostrea tokunagai, Cossmann.

PISCES.

Myliobatis sp.

MAMMALIA.

Elephas antiquus, Fal.
Indeterminable ungulate bones.

[1] Journ. Coll. Sci. Tokyo, vol. xxi, art. 2, p. 93, 1906.

Mr. Tokunaga enumerated the above list of fossils from the principal shell-bearing sands and overlying argillaceous bed of Tabata. It seems to me also quite reasonable that he has put together the fossils from these two beds in one and the same list, for these two beds are not palæontologically and stratigraphically quite distinguishable from each other.

Of the mollusca enumerated by Mr. Tokunaga, I have intentionally excluded *Potamides* cf. *incisus*, Hombr. & Jacq., as it seems identical with *P. fluviatilis*; I also think that *N. livescens* of the author (from Tabata, though not from Oji) is quite different from the species described by Philippi under that name. On the whole, there are known from Tabata twenty-six species of Gasteropoda and fifteen species of Pelecypoda (Lamellibranchia), of which the following twelve are especially abundant: *Nassa livescens*, *Potamides zonale*, *P. fluviatilis*, *Rissoa cerithina*, *R. septentrionalis*, *Ringicula arctata*, *Martesia striata*, *Saxicava arctica*, *Tellina yedoensis*, *Macoma nasuta*, *Cyclina chinensis*, and *Arca granosa*.

Mr. Tokunaga was of opinion that the shell-beds of Oji, Tabata, and Shinagawa were all of marine origin and of similar facies (loc. cit., p. 77, footnote). This seems to me decidedly untenable, because the shell-bed of Tabata is obviously a typical estuarine deposit according to the previously recorded molluses, which are in association with abundant remains of land-plants, and from the lithological character of the sediments; while those of Oji and Shinagawa are deposits from a somewhat deeper, normally saline water, more distant from the coast. Especially in the shell-bed of Shinagawa, we find abundant Foraminifera and Ostracoda, both including typical plankton forms. At any rate it seems certain that these three localities were at that time in one and the same inlet of the sea, which was sheltered and quite free from the action of breakers.

Of an essentially different nature from the estuarine formation is the shell-sand exposed at a distance of 200 metres, in the section at Tabata. From the stratigraphical evidence it is quite certain that the shell-sand is on the same level as the brown and blue clay of the other section, and consequently represents a little higher horizon than the principal shell-bed of Oji and Shinagawa. Mr. Yamakawa collected and determined in the recently found shell-sand the following mollusca:—

Mollusca from the Shell-sand at Tabata.

Gasteropoda.

Volutharpa perryi, Jay.
Nassa japonica, Adams.
Pleurotoma reciproca, Gld.
P. cf. *gracilenta*, Rve.
Natica clausa, Desh.
Odostomia planata, Gld.
Leptothyra sp.
Ringicula arctata, Gld.

Lamellibranchia (or Pelecypoda).

Solen krusensterni, Schrenk.
Machæra pulchella, Dkr.
Panopæa generosa, Gld.
Corbula sp.
Myodora fluctuosa, Gld.
Mactra sachalinensis, Schrenk.
M. sulcataria, Desh.
Raeta yokohamense, Pilsb.
Tresus nuttalli, Conrad.
Tellina venulosa, Schrenk.
T. nitidula, Dkr.
T. nipponica, Tok.
Saxidomus nuttalli, Conrad.
Venus stimpsoni, Gld.
Dosinia exoleta, L.

Tapes sp.
Cardium braunsi, Tok.
C. californiense, Desh.
Phacoides aff. *borealis*, L.
Diplodonta pacifica, Tok.
Nucula insignis, Gld.
Yoldia sp.
Arca tenuis, Tok.
Pectunculus albolineatus, Lischke.
Pecten tokyoensis, Tok.
P. laqueatus, Sowb.

Of these eight species of Gasteropoda and twenty-six species of Lamellibranchia (Pelecypoda), *Natica clausa*, *Panopæa generosa*, *Tellina venulosa*, *Saxidomus nuttalli*, *Venus stimpsoni*, *Arca tenuis*, and *Pectunculus albolineatus* are predominant, whereas *Solen krusensterni*, *Mactra sulcataria*, *Tresus nuttalli*, *Tellina nipponica*, *Diplodonta pacifica*, and *Pecten tokyoensis* are very common.

The comparison of these two lists of fossils shows that only four species—*Nassa japonica*, *Ringicula arctata*, *Solen krusensterni*, and *Tellina yedoensis*—are common to both; whilst the complete absence of the typical estuarine forms is a distinguishing feature of the newly found molluscan fauna. The number of the common species may perhaps be somewhat increased by more extensive and cautious collecting of fossils from both localities; but the striking difference of these two faunas seems to be quite apparent.

On the other hand, the new fauna from Tabata has nearly all the species in common with the fauna from the principal shell-bed of Oji and Shinagawa, which decidedly represents a slightly lower horizon, as mentioned above; the only exception is *Tellina venulosa*, which is so abundant in Tabata, but still unknown from other fossiliferous localities in and near Tokyo. This difference is more remarkable when we take the fact into consideration that this species, now living in great abundance in the surrounding seas of Hokkaido, and rarely found in a diminutive form along the more southern coasts washed by the cold Lyman current, is found in multitudes in the shell-sand of the Narita Series, which is extensively developed in the province of Shimosa and in the part of Musashi lying east of Tokyo. The shell-sand of the Narita Series is considered by Tokunaga to be younger than the shell-beds of Tokyo, taking together the shell-beds of Shinagawa, Oji, and Tabata, while others think them of nearly the same age.

It is necessary here to introduce a short account of the Narita Series from one of my former articles in Japanese, supplemented by later observations.

In the extensive tract of loam, lying east of Tokyo, is a subaerial deposit, without any trace of stratification and sometimes with thin irregular layers of nearly decomposed pumice, is underlaid by a thick complex of marine sand with a little intercalation of clay and argillaceous sand which for convenience sake I called "Narita Series", from the reason of its typical development in the neighbourhood of Narita in the province of Shimosa. The marine sand is sometimes very fine-grained and sometimes coarse, even mixed with shingle, composed chiefly of quartz fragments, and in great contrast to the shell-bearing sand of Tokyo; it is not tufaceous. Cross-bedding is universal. The distribution of fossil shells in the sand is not uniform, but they are found here and there in considerable numbers.

The fossil contents of the Narita Series are almost exclusively confined to Mollusca and a species of Echinoderm, although naturally other fossils, for example, Foraminifera, Corals, and Crustacea, are not excluded, being relatively so seldom met with that they may be considered of no practical value for classification of the beds. Of the Mollusca the great majority belong to the Lamellibranchia (or Pelecypoda), which much exceed the Gasteropoda in number of species as well as in quantity of individuals. The molluscan fauna of the "Narita Series" is equal in number of species to that of the shell-beds of Shinagawa and Oji; but a striking feature of the former is the exceeding preponderance of certain forms over others, the most conspicuous species being *Mactra sulcataria*, *Tapes philippinarum*, *Tellina venulosa*, *Solen krusensterni*, *Diplodonta pacifica*, and *Pectunculus albolineatus*; *Echinorachnius mirabilis* belongs also to the same category, and in some localities it is found almost alone and without the presence of other fossils.

Another characteristic feature of the fossiliferous bed in a typical development is its contents of triturated shell-fragments in great quantity, beside its mineral composition, so that the term shell-sand seems really appropriate. The shell-remains vary in preservation and are generally very water-worn; the Pelecypoda are seldom found with both valves associated. The formation of the fossiliferous bed might have originated just in the same way as obtains at present along an ocean coast exposed to the violent abrading action of mighty waves. The shell-bearing sand of Oji and Shinagawa was formed in a different way; the Pelecypoda are often found with both valves connected and in the position which they assumed during the living state, and there are besides numerous vertical sand or clay-tubes not in the least distorted; such conditions would tend to prove that sedimentation took place in quite calm water.

Stratigraphically the Narita Series, at least in its upper part, is decidedly younger than the shell-beds of Shinagawa and Oji, but whether its lower part is not synchronous with the latter is at present questionable; the faunal difference seems in this case to depend more upon the geographical separation and the difference of the physical conditions of the places where the marine sediments were deposited than on the slight difference of age. The question of the relative geological age of these two faunas is only to be decided by means of a boring at a proper place in the district of the Narita Series, unless the typical Oji fauna is found beneath the shell-sand of the Narita Series.

The sandy gravel bed between the loam and the brown and blue clay of Tabata is considered by me as a special development of the Narita Series, or at least of its upper part; the sandy gravel bed passes on one side into an immense accumulation of gravels of various sizes, and on the other side to fine sand with cross-bedding; fossils are very seldom found in it, but I can safely conclude from material at my disposal [1] that the formation of the deposit is either marine or coastal, at all events so far as the deposit in Tokyo is concerned.

[1] Professor B. Koto and I have collected in the sandy gravel bed of Shibuya (in Tokyo) *Neptunea despecta* and *Cancellaria nodulifera*.

This consideration finds support in the evidence afforded by the shell-sand exposed beneath the sandy gravel bed in the cutting of the Yamanota line at Tabata; it has already been pointed out that the fossil remains from the shell-sand exhibit a certain resemblance to the Narita fauna. As it is found quite isolated in the district in which the Oji fauna occurs—I mean by this the molluscan fauna of the principal shell-bed of Oji and Shinagawa—it is of course not in the typical development of the Narita fauna as would reasonably be expected, but on the contrary it shows a partial similarity to the Oji fauna, as indicated by the absence of *Echinorachnius mirabilis* and *Tapes* aff. *philippinarum* and by the frequency of *Pecten tokyoensis*; the two former species are very abundant in the typical shell-sand of the Narita Series and very seldom found in the Oji fauna, whilst the latter bears quite a reverse relationship. Briefly, the new Tabata fauna seems to show the characteristic features of the Oji and Narita faunas in combination, which have hitherto been found geographically quite separate from each other. This indicates that the life assemblage belongs to a transitional type between the Oji and Narita fauna in regard to both geological and geographical distribution.

About the subdivision of the Diluvial deposits (including Pliocene?) in Tokyo and their correlation with the European standard, various propositions have been made, among others, by Messrs. Brauns, T. Suzuki, and Tokunaga. Professor Brauns,[1] who identified many of the molluscs from the shell-bed of Oji and Shinagawa with the English Crag forms, claimed the shell-bed to be of Pliocene age, and considered the wavy surface of the shell-bed as indicating a significant stratigraphical gap between this and the overlying bed. As a consequence, he adopted the following subdivisions: (1) Upper Diluvium—loam; (2) Lower Diluvium—sandy gravel beds with an intercalating clay-bed; (3) Pliocene—shell-bed of Oji and Shinagawa and the underlying gravel and sand beds. Mr. Suzuki[2] differed from Brauns in regarding the clay and sand beds overlying the shell-bed as Pliocene, while Mr. Tokunaga, in his detailed study of the fossils, was of opinion that the shell-bed of Oji and Shinagawa as well as the overlying sand and clay beds, yielding many fossils at Tabata as mentioned before, must be of Pleistocene age; he considered these beds as forming altogether a complex, but without referring to its relation with the covering sandy gravel bed.

My personal observation about the question led me to conclude that the statement of Brauns regarding the loam and the underlying rock series is correct, but about the other line of boundary Suzuki and Tokunaga's opinions are to be preferred.

I have already often used the name Narita Series for the complex underlying the loam and chiefly composed of sand and gravel beds with some intercalation of thin clay layers at various horizons; for the lowest complex I now wish to propose the name Tokyo Series; the latter consequently includes the principal shell-bed of Oji and

[1] "Geology of the Environs of Tokio": Mem. Sci. Dept. Tokio (University), 1881, No. 4, p. 77.

[2] Explanatory Text to the Geological Sheet, Tokyo, 1887 (issued by Geol. Surv. Japan).

Shinagawa with the Oji fauna and the estuarine shell and plant beds of Tabata. This proposal is made partly for the purpose of avoiding the undesirable method of employing such vague terms as Pliocene or Pleistocene for the beds of Oji, etc. There is no doubt that Professor Brauns was mistaken in claiming the Oji fauna to be of Pliocene age, as also was Mr. Suzuki for the estuarine bed; on the other hand, the statement of Mr. Tokunaga favouring the Diluvial age of the Tokyo Series is in part quite correct.[1] Mr. Tokunaga had determined ten extinct species and 155 species belonging to modern forms; the percentage of extinct species to the living is too small to assume the series to be of Pliocene age. It is, however, not quite clear how far the application of the European standard of ratio between the living and extinct molluscan species can be relied upon for the correlation of the geological age of a certain late Cainozoic formation in Japan, especially in so widely distant a part of the world.

The Diluvial age of the series now under consideration appears to be further supported by additional evidence, afforded by the presence of molar teeth of *Elephas antiquus*, Falc., which it seems have been obtained from the estuarine clay-bed of Tabata. It must also be taken into consideration that the Kendang or Trinil Beds of Trinil, Java, with abundant mammalian remains, are still under dispute as to their geological position; the question being whether the complex is of Pliocene or Pleistocene age. In the present case more uncertainty exists because it is somewhat doubtful whether the molar teeth were found in the topmost bed of the Tokyo Series or whether they were obtained from the overlying sand-bed of the Narita Series.

But practically it is insignificant whether the Tokyo Series is of Pliocene or Pleistocene age, the constitution and general facies of the fauna being now fully known to us by the detailed study of Mr. Tokunaga; one of his conclusions, however, must be considered with great caution, viz. that the sea near Tokyo was inhabited at that time by molluscs of a climate colder than that which now prevails. This generalization is quite untenable, but it is possible that the relative influence of the cold and warm currents alone, which have followed nearly the same course since Jurassic times, when the Behring Strait was opened or any other similar water communication existed between the Polar seas and the North Pacific Ocean, and without any other essential climatic change in reality may have produced the same effect on the marine organisms living in a shallow inlet of the sea as once existed in the region where Tokyo now stands.

Such unconformity in deposition is not unfrequent in estuarine and strand formations, and must not be taken as an indication of an important stratigraphical gap between two successive formations. Professor Brauns also paid early attention to the existence of such unconformity in our diluvial deposits and explained likewise its stratigraphical insignificance; he was only misled by the wavy surface of the shell-bed of Oji and Shinagawa, which he took as

[1] He enumerated *Diplodonta pacifica* among the extinct species; but it is found living in the surrounding seas of Hokkaido and also, though more seldom, along the east coast of Honshyu (main island of Japan).

the boundary between the Pleistocene and Pliocene deposits. This error was soon afterwards justly corrected by Suzuki and later more effectually by Tokunaga.

Of more importance to the discussion is the boundary between the Narita and Tokyo Series, which was once exposed very favourably in the sand ditches along the Owu line at Tabata. The marked difference of lithological characters between the two consecutive beds above and below the boundary-line made the unconformity very striking.

At that time I was inclined to take it as an evidence of time-interval between two deposits; the new discovery of the shell-sand, which is the main subject of the present article, however, entirely deprived me of any confidence in this previous supposition. As mentioned above, we see now at Tabata, on one side the regular downward succession of sandy gravel bed and sand-bed which locally passes to argillaceous sand, arenaceous clay, and the shell-sand with the characteristic transitional fauna between the Oji and Narita fauna, and on the other hand likewise quite a regular succession of the deposits of the Tokyo Series, namely, in ascending order (A) the principal shell-bed of Oji and Shinagawa, (B) sand and clay beds of an estuarine formation. These estuarine deposits of the Tokyo Series lie on the same level as, and in close proximity to, the sand-bed which is the direct continuation of the shell-sand above mentioned. The detailed local researches of Mr. Yamakawa and myself have clearly revealed the total absence of any indication of a stratigraphical break between them. We are therefore obliged to conclude that the variation of sediments is only a local phenomenon and that their deposition took place side by side at the same time. Consequently, the apparent unconformity between the Narita and Tokyo Series must also be regarded as only of minor geological importance.

NOTICES OF MEMOIRS.

On the Value of the Fossil Floras of the Arctic Regions as Evidence of Geological Climates.[1]

By Professor A. G. Nathorst, Hon. Sc.D. Camb., of Stockholm.

Translated from the French original[2] by E. A. Newell Arber, M.A., F.G.S.

Among the problems which are constantly called to mind during geological explorations in the Arctic regions, that of the climates of the past naturally demands special attention. The contrast between the present and the past is there more striking than in any other region. Beneath the snow and ice bordering the Arctic sea, one marvels to find, for example, large corals in beds belonging to the

[1] A paper read before the Eleventh International Geological Congress on August 25, 1910. "Sur la valeur des flores fossiles des régions arctiques comme preuve des climats géologiques," Stockholm, 1910. Also in Compt. Rend. Eleventh Intern. Geol. Congr., Stockholm, 1911.

[2] The English translation has been revised by Professor Nathorst, and references added.

Carboniferous System, or again the remains of Saurians, Ammonites, or Nautiloids, in those of Triassic age. But when one bears in mind the extreme richness of the Invertebrate fauna of the Arctic seas to-day, when one remembers the colossal whales which find their subsistence in these waters, one may be inclined to ask if it has not been an error to conclude, from the occurrence of the fossils above mentioned, that the climate was formerly more genial than it is to-day. Should we not be under-estimating the creative power of life if we imagine that, among the Saurians, the Ammonites, and the Nautiloids, no species has been able to develop which was adapted to life in the Arctic seas? If the Reindeer and the Musk-ox were extinct, who would imagine that these beasts were able to flourish on the scanty vegetation of the high parallels north of 80° of latitude? And who would suppose that such monsters as the Mammoth and the Woolly Rhinoceros could find sufficient nourishment in the poor vegetation of the Tundras or the Coniferous forests? Such examples teach prudence: there is certainly no question which requires so much caution as the problem of deducing from the faunas of the past the climatic conditions under which they flourished.

This remark applies with equal force to the floras. Although to-day the Cycads only occur in warm regions, it would be an error to conclude that the Cycadophyta of the past have always flourished under similar conditions. On the contrary, we must admit that during the Mesozoic period, when these plants were abundant, it would no doubt have been possible to find several species which had adapted themselves to an Alpine climate if such a one had then existed. And if, since then, the differentiation of climates has begun to make itself felt, it would be again a case of overlooking the creative power of life, if we assumed that none of the species of Cycadophytes were able to adapt themselves to a temperate climate in the Polar regions. Again we meet with difficulties, even when we study the plants of the Tertiary period, which are assigned to genera still living. Our Common Juniper (*Juniperus communis*, Linn.), which exists in Northern Europe as far north as the North Cape, exceeds by 20 to 25 degrees of latitude, in the Eastern Hemisphere, the northern limit, not only of the other species of the genus, but also the whole family of the Cupressineæ. Now, if one imagined that the Common Juniper was extinct, one would naturally draw conclusions relative to the fossil remains from the distribution of the other species. And one would consequently suppose that it lived under a climate much warmer than is actually the case. One would scarcely imagine that we were concerned with a plant adapted not only to temperate, but also to Arctic, climates. (One finds the Juniper, on the western side of Greenland, up to the 64th parallel.)

These examples counsel prudence, and the matter should be treated with judgment and circumspection. But, even if it is necessary to make reservations, when one seeks to determine from the fossil plants the nature of former climates in the Arctic regions, at least one cannot doubt that they were distinctly warmer than that of the present day. The difficulty of explaining these former climates, especially when one has to take into consideration the length of the winter

night, is without doubt the reason which has led some scientists to evade the question, instead of seeking to solve it. It is indeed a case of evading the question when it is boldly asserted that the plant-remains, on which Heer[1] has based his theories of ancient Arctic climates, have been drifted by marine currents to the places where they have been found.

It is not to be disputed that plant debris may be transported in water for a very great distance without being damaged, provided that they are carried at a sufficient depth to escape the influence of the movements of the surface layers of the water. When Agassiz was engaged in dredging on the American coasts, he found that the bottom of the sea—sometimes to a depth of nearly 3,000 metres—was covered with plant debris, such as wood, branches, leaves, seeds, and fruits, in all stages of decay. Also, in certain places, these remains were still fairly abundant at a distance of 1,100–1,200 kilometres from the shore. This distance corresponds to about 10 degrees of latitude. It is thus proved that the remains of plants may be transported for very considerable distances. But this is true only of marine deposits. If we are concerned with freshwater sediments, the example given has no bearing on the case.

One might, however, reasonably suppose that a river, flowing in the direction of the meridian from south to north, might have carried from the southern regions leaves and other fragments of vegetation which became buried in some deposit of the stream itself, or of a lake, which it traversed, or of its delta. This is a possibility which must not be neglected, but on the other hand it must not be treated as though it were an ascertained fact, since we do not know how far it applies to the case in point.

The fact is, it is puerile to attempt to draw conclusions as to the ancient climates of the Arctic regions, before the nature of the deposits in which the fossil plants have been found has been ascertained. It is especially important that an attempt should be made to answer the question, did the plants once flourish in the neighbourhood of the deposits in which they are found, or were they transported from far-away lands? It is this question which an attempt will here be made to solve, by furnishing a concise résumé of the principal beds containing fossil plants in the Arctic regions.

In Bear Island,[2] and in Ellesmere Land,[3] beds extremely rich in plant-remains are met with belonging to the Devonian system. The fossil plants of Bear Island occur in the series of beds which also include several seams of coal. Beneath the coal, which is composed essentially of the bark and trunks of *Bathrodendron*, one finds, as elsewhere, bituminous schists containing roots, and from this one can show that the plants of which we speak flourished, at least in part, in situ. This is likewise proved by the actual nature of the plants, as much in the older beds with *Archæopteris fimbriata*, Nath.,

[1] O. Heer, *Flora fossilis arctica*, vols. i–vii, 1868–83.

[2] A. G. Nathorst, "Zur Oberdevonischen Flora der Bären Insel": Kongl. Svenska Vet.-Akad. Handl., vol. xxxi, No. 3, 1902.

[3] Id., "Die Oberdevonische Flora des Ellesmere Landes": Rep. 2nd Norweg. Arctic Exped. in the Fram, vol. i; Christiania, 1904.

as in the more recent with *Pseudoborinia ursina*, Nath. The latter species has been found with large stems or rhizomes, as well as very small ones, only a few millimetres in diameter, to which extremely delicate, almost membranous, leaves are still attached. It is hence quite certain that there is here no question of the plants having come from distant regions. The materials have not been sorted out. One sees a medley of branches, small and large, and the perfection of the preservation of their delicate leaves demonstrate conclusively that they have not undergone transportation from afar. The same applies to *Archæopteris fimbriata*. The beds of coal, the clay with rootlets, and the very nature of the plants themselves, all point to the same conclusion, namely, that we have here a flora which flourished in part on the very spot where it is now found.

As I have already pointed out in my description of the Devonian flora of Ellesmere Land, one arrives at the same conclusions here also, and it is unnecessary to enter into further details.

In the Arctic regions, Culm deposits, yielding fossil plants, are known from Spitzbergen,[1] from the north-east of Greenland,[2] and probably from the south of Melville Island, in the Arctic Archipelago of America.

We will here concern ourselves only with Spitzbergen, although it may be mentioned in passing that the flora of the Culm discovered by the Danish expedition in North-East Greenland, in latitude 81° North, consists of nearly the same species as that of Spitzbergen. The latter flora has been observed in many localities up to 79° of latitude. It is characterized by the presence of *Stigmaria*, with appendicular organs radiating in all directions, still in continuity and penetrating the clay beneath. We are thus able, in several places, to observe the presence of *Stigmaria* in situ, which furnishes undeniable evidence of the fact that the plants lived in the place where we now find them. The stems of *Lepidodendron* found in the same place have a diameter of at least 40 cm. It would be superfluous to give other examples, for one can scarcely doubt that the plants of the Culm have flourished in the very place in which they are now found, or in its vicinity.

On the other hand, the observations which relate to the Triassic plants of Spitzbergen and Eastern Greenland are somewhat different. The latter ones belong to the Rhætic Series and include several species of *Pterophyllum*, *Podozamites*, *Cladophlebis*,[3] etc. In Spitzbergen one finds them as far north as 78°.[4] Neither there nor in Eastern Greenland, where one meets with them between the 70th and 71st parallel, are they associated with beds of coal, but the manner in which they occur in Greenland indicates that in no case have they

[1] A. G. Nathorst, "Zur Paläozoischen Flora der Arctischen Zone": Kongl. Svenska Vet.-Akad. Handl., vol. xxvi, No. 4, 1894.

[2] Id., "Contributions to the Carboniferous Flora of North-Eastern Greenland": Meddelelser om Grönland, vol. lxiii; Copenhagen, 1911.

[3] N. Hartz, "Planteforsteninger fra Cap Stewart i Östgronland": Meddelelser om Grönland, vol. xix; Copenhagen, 1896.

[4] A. G. Nathorst, "Zur Mesozoischen Flora Spitzbergens": Kongl. Svenska Vet.-Akad. Handl., vol. xxx, No. 1; Stockholm, 1897.

travelled from very distant localities. One has not with certainty observed any marine petrifactions associated with the plants, but it has not yet been clearly determined whether the Triassic beds with fossil plants of Spitzbergen are of marine or of freshwater origin.

The most ancient Jurassic sediments of Spitzbergen are marine, and belong to the Sequanian stage. There was consequently a long interruption in sedimentation after the formation of the Rhætic beds.[1] The upper part of the Jurassic formation (Portlandian) furnishes a series of plant-bearing sandstones, seams of coal, and beds of undoubted freshwater origin, containing *Unio* and *Lioplax polaris*. The fossil plant-remains belong to two different floras, one, the more ancient, being characterized by the presence of *Ginkgo digitata*, Brongn., sp.; the other, the more recent, by *Elatides curvifolia*, Dkr., sp. The two floras are associated with beds of coal, and one may here also put forward the view that the plants originally flourished in the place where they are now found. One of the coal-seams at Cape Boheman furnishes a great abundance of *Podozamites* and *Pityophyllum*; sometimes the surface of the schists is as completely covered with the leaves of *Ginkgo digitata*, as the soil beneath a living *Ginkgo* tree may be in autumn. Since branches and seeds of the same plant are also associated, it is natural to suppose that a Ginkgo forest occurred not far away from this spot. The same observation applies to *Elatides curvifolia* of the more recent flora, which occurs locally in the freshwater beds containing *Unio* and *Lioplax*. Floras of the same age and composition are also known from King Karl's Land, the islands of New Siberia,[2] from Northern Siberia, and Arctic Alaska.

The Neocomian Series of King Karl's Land is overlain by sheets of basalt, often amygdaloidal, and containing chalcedony and agates. Fragments of silicified woods, large and small, also occur here, and these, without doubt, owe their mineralization to the volcanic phenomena. Some of these trunks are fairly large, and I have myself measured one, which, although incomplete, was 70–80 cm. in diameter, and showed 210 annular rings. Some of these remains consist of the lower portion of the trunk and the primary ramifications of the roots.

The microscopic examination of these specimens, undertaken by Dr. W. Gothan,[3] has shown that the annual rings of the fossil stems from King Karl's Land were much more accentuated than those of stems found in the corresponding beds of the European continent, which indicates that the trees lived in a region where the difference between the seasons was extremely pronounced. They cannot therefore have been transported from the south by marine currents, and as the trunks found in the corresponding beds of Spitzbergen[4] show the

[1] A. G. Nathorst, "Beiträge zur Geologie der Bären Insel, Spitzbergens, und des König Karl Landes": Bull. Geol. Inst. Upsala, vol. x, 1910.

[2] Id., "Über Trias und Jurapflanzen von der Insel Kotelny": Mém. Akad. Imp. Sci. St. Pétersbourg, ser. VIII, vol. xxi, No. 2, 1907.

[3] W. Gothan, "Die fossilen Hölzer von König Karls Land": Kongl. Svenska Vet.-Akad. Handl., vol. xlii, No. 10, 1907.

[4] Id., "Die fossilen Holzreste von Spitzbergen": Kongl. Svenska Vet.-Akad. Handl., vol. xlv, No. 8, 1910.

same peculiarity, it is quite safe to conclude that we are here concerned with large trees, which have actually flourished in these latitudes, and which have not been transported from more southern regions.[1]

The Cretaceous System, as we know it, is represented in Western Greenland, between the parallels of 69° and 71°, by an important series of beds containing fossil plants belonging to the Urgonian, Cenomanian, and Senonian, the two first mentioned containing coal-seams. I have been able to show, as the result of the studies which I made in Greenland in 1883, that beds, full of roots, underlie those containing fossil plants at Unartoarsuk, as well as at Igdlokunguak. Without doubt the Urgonian flora, like the Cenomanian flora, is a relic of vegetation which once flourished in the same regions where we now find the fossils. But, on the contrary, the Senonian flora, or flora of Patoot, is in part contained in marine beds, containing *Inoceramus*, etc., and thus it may have been transported from some distance. The Urgonian flora, or flora of Kome, is composed of Ferns, Cycadophytes, and Conifers, while the Cenomanian or Atane flora, in addition to arborescent Ferns (*Dicksonia*) and Cycadophytes (*Pseudocycas*),[2] is particularly rich in the leaves of Dicotyledonous trees, among which are found those of planes, tulip-trees, and bread fruits, the last mentioned closely resembling those of the bread fruit-tree (*Artocarpus incisa*)[3] of the islands of the Southern seas.

In the limited space at my disposal, I have had to be content with a brief summary of the strata containing fossil floras of Palæozoic and Mesozoic age. But, from what has been said, it is clear that we have every reason to regard the floras of the Devonian, Culm, Jurassic, and Cretaceous of the Arctic regions as being composed of plants which flourished in these very regions. It has not been definitely proved that the Triassic flora has been transported from more Southern regions by marine currents, but there is still some uncertainty on this point.

In relation to the present problems, the Tertiary floras are undoubtedly the most important, and for this reason I will enter into the subject in some detail. But the materials are so wonderfully rich

[1] It may be mentioned here that a silicified *Dadoxylon* from the Carboniferous deposits of Spitzbergen described by Dr. Gothan (loc. cit.) does not show any annual rings at all, precisely as is the case with the corresponding Palæozoic stems of Europe. As observed to me by Mr. Th. Halle, this is a most curious circumstance, since the darkness during the long winter night in those regions—provided that the position of the North Pole was the same as now—ought to have caused an interruption of the growth, even if the climate was a warm and genial one. As the specimen, however, was not found in situ it is possible that it originates from some marine deposit into which the wood had been brought by ocean currents from more southern latitudes. But also a *Dadoxylon* from the Triassic of Spitzbergen shows only slight indications of annual rings (Gothan, loc. cit.).

[2] A. G. Nathorst, "Paläobotanische Mitteilungen, 1 und 2. *Pseudocycas*, eine neue Cycadophytengattung aus den Cenomanen Kreideablagerungen Grönlands": Kongl. Svenska Vet.-Akad. Handl., vol. lxii, No. 5, 1907.

[3] Id., "Über die Reste eines Brotfruchtbaumes, *Artocarpus Dicksoni*, n.sp., aus den Cenomanen Kreideablagerungen Grönlands": Kongl. Svenska Vet.-Akad. Handl., vol. xxiv, No. 1, 1890.

that I shall have to restrict myself to giving some examples indicating the nature of the beds containing the Tertiary plants in Spitzbergen, Iceland, and Greenland. More especially, I shall recall that they are found at 79° of North latitude in Spitzbergen; on the east coast of Greenland between 74° and 75°, and on the west coast between 69° and 73°; at Lady Franklin Bay, in Grinnell Land (81° 42″); in Ellesmere Land between 77° and 78°; on the River Mackenzie at 65°; in Alaska south of 60° (and therefore outside the Polar Circle); and lastly in the islands of New Siberia (75°). Iceland, it is true, is outside the Polar Circle, but nevertheless its Tertiary flora may be included in this consideration.

The Tertiary formations of Spitzbergen, which have a thickness of perhaps 1,200 metres or thereabouts, contain fossil plants and seams of coal, both in the upper and lower beds, though the middle portion is marine. As an example of the deposits with fossil plants from the base of this formation the shales called the 'Taxodium Shales' at Cape Staratschin, may be mentioned. These are fine-grained black soft shales, which form the roof of a small bed of coal. In the shales the leafy branches, the flowers, the seeds, and the ovuliferous scales of the Swamp Cypress (*Taxodium distichum miocenum*), the leafy branches of *Sequoia Nordenskiöldi*, Hr., and *Libocedrus Sabiniana*, Hr., are particularly common. There are also associated a large number of remains of Gramineæ, Cyperaceæ, several species of Pines and Firs, a *Potamogeton*, and the leaves of various Dicotyledonous trees. Thus, as Heer has shown, one is dealing here with freshwater sediments, in the neighbourhood of which it is evident that the Swamp Cypresses have formed forests, as in the swamps in the southern portion of the United States to-day. This conclusion is also confirmed by the occurrence of the remains of rather numerous insects, among which there are a score of Coleopterids, two of which are hydrophilous Coleopterids (*Hydrobius* and *Laccophilus*).

These beds with fossil plants, at the base of the Tertiary formations of Spitzbergen, are overlain by thick marine sediments. In their upper portion, the latter show indications of a retreat of the ocean and a recurrence of freshwater conditions. It is possible that the leaves found in the lower part of the higher horizon containing fossil plants have been transported from afar by a river, and deposited near its mouth, but as regards the upper portion, deposition must have taken place in vast swamps, on which the majority of the plants actually lived. In these beds one notices thin seams of coal, a great quantity of leafy branches, and also cones of *Sequoia Langsdorfii*, Brongn. (which resembles the Red Wood of California, *Sequoia sempervirens*, Endl.) and the Swamp Cypress (*Taxodium distichum miocenum*). Here and there a large Horsetail (*Equisetites Nordenskiöldi*, Nath.) occurs in such abundance that one would imagine that it formed small forests. There are also associated rhizomes, with their roots and tubercles still attached. I may mention in passing that *Equisetum arcticum*, Heer, occurs in the same manner in the lower zone of the plant-bearing beds. There also occurs a great abundance of *Osmunda spitzbergensis*, Nath., and on the same horizon nodules of clay ironstone, entirely filled with leaves and stems of the

latter plant, in which the tissues have been so completely mineralized that one can study the microscopic structure as minutely as in the living *Osmunda*. One sees in the carbonaceous petrified layers rootlets and spores of ferns, as well as fragments of branches, etc. This might justly be called a mineralized peat. Among the Dicotyledonous trees, the leaves of which occur in great quantity, one finds leaves of all dimensions belonging to the more common species. I have examples, among others, of the leaves of *Ulmiphyllum asperrimum*, Nath., varying from 1–17 cm. in length. All the observations indicate that we have here a deposit formed by the delta of a stream, passing through a marsh, on which grew trees requiring humidity, while the remains of other plants which lived at some distance away have been transported, either by the wind or by water, and become mingled with those of the marsh.

The beds of this horizon, discovered at Cape Lyell, are remarkable for the enormous quantity of leafy branches of *Sequoia Langsdorfii*, leaves of *Grewia crenata*, Hr., and of *Acer arcticum*, Hr., the fruits of the last mentioned also occurring. A bed full of rootlets was also met with, showing that the plants flourished on the spot where they are now found. Among the marsh plants an *Alisma* occurs. Among the Dicotyledonous trees of this horizon are Poplars (*Populus*), Willows (*Salix*), Alders (*Alnus*), Birches (*Betula*), Hornbeams (*Carpinus*), Hazels (*Corylus*), Beeches (*Fagus*), Oaks (*Quercus*), Elms (*Ulmus*), Planes (*Platanus*), Magnolias (*Magnolia*), Limes (*Tilea*), and Maples (*Acer*), etc. We can thus show that during the Tertiary period all these plants have flourished at 78° or 79° of latitude. In Grinnell Land we find, even at nearly 82°, the Swamp Cypresses, the Spruces, Pines, Firs, Poplars, Birches, Elms, Limes, etc.

In Iceland the Tertiary flora may be studied in the volcanic tuffs or in the alluvium formed from them, and at Brjàmslaekur, for instance, in a deposit which may be compared with a laminated peat. Thus, as Heer had suggested, and Thoroddsen has proved, we here meet with formations laid down above sea-level, which are overlain by thick basaltic beds. A glance at the specimens from Brjàmslaekur serves to show that we have here to deal with freshwater deposits. M. Östrup's[1] microscopic examination of the Diatoms, found in the same beds as the fossil plants, confirms this conclusion, for they are freshwater species.

Among the beds furnishing Tertiary plants, so abundant in Greenland, I will only mention that at Harön, near Waigattet. Here the plants occur either in a true basaltic tuff or in an altered tufa or a sediment formed from it, and overlain with basalts.

The investigation of two beds, which I made in 1883, has proved that they cannot be other than formations laid down above sea-level. In one of these deposits the fossil flora consisted almost exclusively of leaves of the Maple (*Acer*), crowded like those which cover the ground in autumn, and among these leaves large samaras, like those of

[1] E. Östrup, "Diatoméerne i nogle islandske Surtarbrandlag," pt. i: Meddel. fra Dansk Geol. Forening, No. 3; Copenhagen, 1896. Pt. ii, ibid., No. 6, 1900.

A. otopteryx, Gp., occur. In another bed the tuff was formed of cinders and small lapilli, and the way in which the vegetable fragments were embedded leads one to suppose that the branches, leaves, and fruits of the trees were broken off by a shower of cinders and lapilli. A medley of silicified branches of different sizes occurs, and among them are the cones of the Spruce, the nuts of the Walnut (*Juglans*), and the Hickory (*Carya*), with the leaves of *Ginkgo*, etc. In the finer tuffs we likewise find the leaves of the Walnut, the leaves and fruits of an Ash (*Fraxinus macrophylla*, Hr.), and the leaves of species common in the Tertiary flora of Greenland, such as the Plane, Oak, Chestnut, Beech, etc.

The presence of the leaves of *Potamogeton*, associated with a freshwater mussel (*Unio*), indicates that the deposits were of freshwater origin. Some of the branches of the trees are silicified and exhibit, under the microscope, an extremely well-preserved structure. M. J. Schuster, who has undertaken a preliminary examination of these remains, concludes that they all belong to one species, which was probably either an arborescent member of the Leguminosæ or of the Rosaceæ. It is clear that we have here to deal with fragments of vegetation broken off by a shower of ashes and entombed in them, though some fragments may have been transported into a freshwater basin containing mussels and aquatic plants.

The Tertiary plants discovered by the Norwegian Expedition to Ellesmere Land deserve special mention on account of their state of preservation. They consist almost entirely of branches of *Sequoia Langsdorfii*, contained in a bituminous laminated clay, from which I have been able to remove them by a process of washing, with the result that they are now isolated like dried specimens in a herbarium.

I must here bring to a close my review of the ancient plant-bearing beds of the Arctic regions. We may conclude that, in the greater number of cases, it is evident that the plants really grew in the regions in question. Although we know of fossil plants in some marine deposits, as for instance in the Senonian of Greenland, and perhaps also in the Trias of Spitzbergen, these are exceptions which lack importance, since other deposits, of a closely corresponding age, are of freshwater origin. While it may be admitted that, even in Spitzbergen, part of the Tertiary flora may have been transported from a more or less distant country by a river, yet other deposits, on approximately the same horizon, indicate that the greater number of the species, and among them the most important types, have actually flourished in the region itself.

Taking into account the facts which I have enumerated, it is evident that the fossil floras of the Arctic should be still regarded as the foundation of every discussion of the former climates of this region. How are these favourable climates to be explained? That is a question to which we are not able to reply at the present moment, and of which the solution belongs to the future.

REVIEWS.

I.—The Geology of Water Supply. By Horace B. Woodward, F.R.S., F.G.S. 8vo; pp. xii, 340. London: Edward Arnold, 1910. Price 7*s.* 6*d.* net.

A HANDY book on Water and Water Supply has long been needed by the public; now, thanks to Dr. J. E. Marr, F.R.S., the editor of Mr. Arnold's Geological Series, the task has been undertaken by Mr. Horace B. Woodward, whose forty years connexion with the Geological Survey of England and Wales has given him long practical acquaintance with the principal water-bearing strata of our Island, while his advice has been frequently requisitioned by Government Commissions, by Water Companies, as well as by private persons, when seeking water, whether for camps, for cities, or for country residences.

It is not only essential for towns, for brewers, and many other manufacturers to obtain an abundant supply of water, but it must, in addition, be of good quality. There are cases upon record of deep borings having been undertaken by towns in order to obtain a large, constant, and pure supply of water, which have resulted satisfactorily both as regards quantity and constancy, but alas! the water proved too saline for drinking, and the cry of Coleridge's "Ancient Mariner" went up from that city of

> "Water, water everywhere,
> Nor any drop to drink"!

But that is only one of the evils to be guarded against by the engineer and chemist as well as the geologist in search of water. There is the fruitful and ever-present anxiety arising from the introduction of organic pollutions to which the water in every inhabited area is liable. Most suspicious or doubtful water which exhibits any proportion of such contamination has probably been derived from a shallow well or a river; but even deep wells or spring water are liable to contain at times some noxious germs through drainage percolation in the adjacent soil.

In rural districts (now happily rarely), the well for drinking-water and the cess-pit are sometimes to be found in dangerous proximity, and the very source of domestic water supply may thus become contaminated.

Going back to the original "sources of water supply, these depend almost wholly on rainfall, and the consequent springs, rivers, and lakes to which it gives birth, also on the geological structure which enables certain rocks to store large supplies of the rain that has percolated through the soil. As these factors are subject to extreme variation, so the problem of obtaining wholesome and adequate supplies may be either simple or fraught with great difficulty and uncertainty" (p. 2).

"Freshwater is required in all regions, from the tropics to the poles, and at different elevations, so that recourse must be had in some situations to the melting of snow or glacial ice, to natural water-holes, in arid regions, or to the sinking of wells along a dry river course, and to the distillation of sea-water, mostly on the

ocean, but sometimes on the land" (as in some cities on the West Coast of South America).

"In primitive times, springs, brooks, rivers, pools, and lakes yielded the necessary supplies, and the earliest settlements were made in places where water could be thus freely obtained."

The digging of wells must have been amongst the very earliest achievements of mankind, as is evidenced by their frequent mention in the time of the patriarchs (Gen. xxvi, 15 and 18; Exod. xv, 27; Deut. vi, 11, etc.). A proverb of the East says—"To have digged a well, planted a tree, married a wife, and begotten a son are the evidences of a well-spent life." The Chinese, Babylonians, Egyptians, Greeks, Romans, and Moors have left ample testimony of their genius both in the sinking of wells and in the constructing of aqueducts. No doubt the engineer long antedated the geologist in all matters of water supply; but we must now always take the geologist into consideration when in search of drinking-water.

In these days in which science holds so large a share in all our undertakings, we cannot trust any longer to the 'water-finder' with his 'divining-rod'. As every child now expects to be told 'the why and wherefore in all things', it is not surprising to find men of experience looking askance at the diviner, with his forked hazel-twig or 'dowsing-rod', professing to show to the uninitiated, by some occult process, which he himself cannot explain, where and at what depth water may be found. It is interesting to know that the 'divining-rod' dates back to the earliest historic times, and was used for a variety of purposes, e.g., to prove the site of old landmarks, to detect crime, to guide the traveller in his right course, and moreover, the rod being attracted by all metals and in a certain order, it was employed in search of mineral lodes.

With the care and accuracy which always characterizes the author's work, Mr. Horace Woodward personally conducts his readers (of course umbrella in hand) through the water-bearing rocks and also through the non-water-bearing ones, explaining their disturbances and faults, their thicknesses, and other characteristics.

We are reminded how much of the rainfall is lost by evaporation, by absorption, by vegetation, and how porous beds take in the water, and what beds arrest its downward progress. And so we pass on to consider rivers, floods, and the drainage of land, of swallow-holes, pipes, springs, and river-courses, and what happens to our rivers when pumping is carried on upon a large scale to supply such thirsty souls as inhabit great cities like modern London. The economy of springs of all kinds is discussed and why some are constant and others not.

Wells next engage the reader's attention, and we discover that they are of many and various kinds, as 'dip-wells' by the roadside, and draw-wells worked by bucket and windlass, sometimes going to a depth of 160 feet. In some cases horizontal wells, or adits, are driven into the sides of hills to open up springs, or to tap the water-bearing strata below. Artesian wells and borings are also described, both flowing and non-flowing.

The water-bearing strata of England receive special attention, several chapters being devoted to their description. The quantity

of water held in the chalk by capillary attraction is very remarkable. One square mile of dry upper chalk, one yard in thickness, contains nearly 3,500,000 gallons of water, and when saturated holds 200,000,000 gallons.

In the New Red Series we have a great thickness of water-bearing rocks. De Rance has recorded a well at Cardiff carried to a depth of 244 feet through red and green Keuper Marls which yielded a supply of 12,000 gallons per hour; and G. H. Morton records that twelve public wells, 4 miles from Liverpool Town Hall, gave an average daily yield amounting to 12,703,770 gallons. We note that much of the water from the Bunter Sandstone is hard (9° to 15°), and its hardness is said to increase with the age of the wells. But this hardness does not detract from its merit in the manufacture of Burton ales.

Prospecting for water nowadays, as described by the author, is by no means so simple a process as that recorded when Moses smote the rock twice with his rod and the water came out abundantly (Numbers xx, 11). Much care and geological knowledge now enter into the task, and maps and sections must be consulted; the dip or inclination of the beds and their thicknesses, the presence of faults, and the physical features of the ground have all to be taken into consideration. But we cannot follow the author step by step in his aquatic investigations, suffice it to say that forty-four well-chosen illustrations aptly aid the careful descriptions of earth-structures and clearly put before the reader all the salient points in water-geology, now a special branch of geological science. Happy is the present-day student who can enjoy all the advantages of Arnold's Geological Series as his guides and instructors, and who, whenever thirsty, can turn to Horace Woodward's abundant geological water supply, to obtain which no divination is required beyond a fee of 7*s.* 6*d.*

II.—Water Supply and Sanitation.

1. The Water Supply of Sussex from Underground Sources. (*Supplement.*) By William Whitaker, F.R.S.; with contributions by H. R. Mill, LL.D., and H. F. Parsons, M.D. London: printed for H.M. Stationery Office, and sold by E. Stanford, Long Acre, and T. Fisher Unwin, Adelphi Terrace. 8vo; pp. viii and 125 to 255. With Rainfall Map. 1911. Price 2*s.* 6*d.*

TWELVE years have elapsed since the publication of the original Memoir on the Water Supply of Sussex by Mr. Whitaker and Mr. Clement Reid. The Supplement is paged continuously with that work, and contains a general index to its full contents: and although the Supplement is longer by seven pages than the former memoir, and has in addition a colour-printed rainfall map, the price is less by 6*d.*

In his introductory remarks, Mr. Whitaker calls attention to the more noteworthy wells of Sussex and the supplies of water yielded by them. Deep borings seem generally to add to the estimated thickness of formations, as in the case of the Wadhurst Clay, which is reckoned to be 230 feet or more at Balcombe and Hellingley; but there is

considerable difficulty in classifying the subdivisions of the Hastings Series. The Chalk, which is 790 feet thick at Chichester, has been proved to a depth of a little over 1,000 feet at Goodwood, and its full thickness there is reckoned to be about 1,200 feet. A map of the underground water-contours in the Chalk between the River Cuckmere and Eastbourne, is reproduced from a paper by Mr. H. M. Whitley; and although it represents observations taken between 1885 and 1889 it is interesting in showing the curves and fluctuations in the water-table.

Along the coastal Chalk tracts the level of the underground water rises and falls with the tide; and in some cases, as at Portslade, brackish water has been tapped by boring.

Dr. Mill remarks that "The distribution of average rainfall over the county corresponds very closely with the configuration of the ground, which in turn is dictated by the geological structure". The Alluvial tracts near Rye annually receive 25 inches of rainfall, the South Downs more than 30 inches, and near Upper Waltham probably more than 40 inches. Ashdown Forest, again, has a rainfall of 35 inches or more. It is noted that October is the wettest month, November, December, and January or September coming next. Thus, as remarked by Dr. Mill, so much rain falling during winter months, the county is favourably situated for accumulating a large quantity of underground water.

Apart from the many records of well-sinkings and borings, Mr. Whitaker contributes notes on springs, bournes, and swallow-holes; and also discusses the important question of contamination of waters, a subject exemplified by reports of cases dealt with by the Local Government Board.

2. Water Supply of Northampton.—Mr. Beeby Thompson, who as one of the authors of the Geological Survey Memoir on the Water Supply of Bedfordshire and Northamptonshire (1909) contributed a particular account of the old wells and other sources of supply for Northampton, has published an interesting, instructive, and more elaborate history of the town springs, wells, and water schemes (Journ. Northants Nat. Hist. Soc., vol. xv, 1909–10). The work is well illustrated with map, plans, and pictorial views of wells, pumps, conduits, and other structures connected with waterworks. It is noted that the "Scarlet Well" probably derives its name from the reputation of its water for giving to cloth a brilliant scarlet with the appropriate dyes in use in the thirteenth century or before. [We learn that the work can be purchased at Northampton from Mark & Co., price 1*s.* 6*d.*]

3. The Influence of Underground Waters on Health is a subject that was brought before the Royal Sanitary Institute (Journal, vol. xxxi, p. 457, 1910) by Mr. Baldwin Latham. Thus "Typhoid fever has been shown to break out not unfrequently after heavy rain", when the ground-water has been low. The rain then washes out the impurities from the porous strata as it descends to feed the ground-water from which domestic supplies are drawn. "When there is a large quantity of water in the ground we have healthy years, except when such high water follows a period of very low water."

4. Water Supply of the United States.—We have received a number of Water Supply Papers published by the United States Geological Survey. No. 255, "Underground Waters for Farm Use," by Mr. M. L. Fuller, is a general treatise on water supply and sanitary matters, including methods of sinking and boring, cost, etc. It is well illustrated. No. 254, "The Underground Waters of North-Central Indiana," is by Mr. S. R. Capps, with a chapter on the chemical characters of the waters by Mr. R. B. Dole. A full account is given of the geography, the geological formations and structure of the region, of the ground waters, artesian areas, and the supplies of water to various localities and for various purposes. No. 240, "Geology and Water Resources of the San Luis Valley, Colorado," by Mr. C. E. Siebenthal, deals with the geography and geology, the climate, agriculture, the alkali soils and the methods of irrigation, the springs, underground waters, flowing and non-flowing wells. Most of these subjects are also dealt with in No. 221, "Geology and Water Resources of the Great Falls Region, Montana," by Mr. C. A. Fisher. Other papers treat of the surface-water supply and the water powers of various regions in the United States.

5. Desert Water Supplies.—In the *Cairo Scientific Journal* (vol. iv, July, 1910) Mr. G. W. Grabham has questioned some of the explanations given by Mr. H. J. L. Beadnell with respect to the flowing wells in the Nubian Sandstone of Kharga Oasis (see Geol. Mag., 1908 and 1909), and suggests "that the constituents of sandstone, though incompressible, are slightly elastic, and when a bore is opened the ground in its neighbourhood may actually subside owing to the reduction of hydrostatic pressure beneath. This subsidence would react on the yield of the well in two ways, namely, expression of the accumulation of water and reduction in size of the sandstone pores, which, though very slight, would tend to reduce the rate of flow. When a bore is closed, the static pressure in its neighbourhood increases and again tends to elevate the ground". Mr. Beadnell replies in the same Journal (vol. v, January, 1911), and observes that "Even admitting, for the sake of argument, that the water held in the pores of a porous bed could be squeezed out by the pressure of the overlying rocks, we are faced by the difficulty of explaining how the water ever obtained access to the beds in the face of such pressure, which surely would have obliterated all such pores; or, again, how the water having been once expelled, could ever again be replaced". He mentions that the porosity of the Nubian Sandstone "varies both horizontally and vertically to a considerable degree", and that well-known facts connected with the fluctuation and depletion of artesian waters do not support Mr. Grabham's contention.

III.—The Natural History of Coal. By E. A. Newell Arber. pp. x, 163, with 21 text-illustrations. Cambridge: at the University Press, 1911. Price 1*s.* net.

THIS little handbook gives in clear and concise language a statement of the leading facts and theories concerning the various forms of coal and their origin, and commendable judgment is shown by the author in dealing with controversial matters. Space is found for

a brief account of the history of coal, and, as the author remarks, it is not a mineral but a rock. Using the term in a popular sense he includes "Anthracite, the Humic or so-called Bituminous coals, the Sapropelic coals, which include the Cannels and Bogheads, the Brown coals, Lignites, and Peat". Their chemical properties, physical characters, and stratigraphical positions are duly pointed out, and the author then deals with the origin of peat, lignite, and the several varieties of coal, especially those of Carboniferous age. That there was an excessive amount of carbon dioxide in the atmosphere of the Carboniferous period is regarded as extremely doubtful. The "Peat-to-Anthracite theory" is rejected. Carboniferous coals were formed quickly, and although in the initial stage they may have resembled peaty deposits they did not necessarily pass through the stages of lignite, etc. Both peat and coal have been formed under a variety of circumstances, and the theories of 'growth-in-situ' and 'drift', as applied to coal, may be equally true. It is shown how coal may be formed under very different circumstances and from very diverse materials. Biochemical changes in plant debris were brought about by bacteria, and the author is led "to attribute a considerable share in the coal building of the Humic, Sapropelic, and Anthracitic types to regional, if not thermal, metamorphism".

As a companion volume of small dimensions, we may commend No. 21 of Gowan's Nature Books, 1909, price 6*d.* net, entitled *Fossil Plants*, and comprising sixty excellent photographs illustrating the flora of the Coal-measures, with explanatory notes, by Mr. Arber.

IV.—Geology for Engineers. By Lieut.-Colonel R. F. Sorsbie, R.E. pp. xxvii, 423, with 94 text-illustrations. London: Charles Griffin & Co., 1911. Price 10*s.* 6*d.* net.

THIS is a conscientious attempt to place before engineers all the geological information that may concern their professional undertakings. About half of the volume is taken up with the matter of an ordinary textbook of Geology: with Dynamic and Structural Geology, with Minerals, Mineral Chemistry, Crystallography, Rock-forming Minerals, and Rocks, and with Stratigraphy and Palæontology. There are illustrations of some of the commoner invertebrate fossils, brief descriptions of both invertebrata and vertebrata, and of the ranges in time of some prominent forms. A general account is given of the geological systems in Britain, and references are made to the occurrence of equivalent formations in various parts of the world. Here the information, though evidently sought out with care, is in some respects seriously behind the times. The tables of strata in North America, Australia, New Zealand, and South Africa are taken from Prestwich's Geology, vol. ii, 1888. Thus it comes to pass that the Acadian and Georgian (Middle and Lower Cambrian) are misplaced and grouped with Primordial under "Lower Silurian", while the Oriskany and Helderberg Beds, now grouped with the Devonian, are placed in Upper Silurian. *Eozoon canadense*, moreover, is recorded as a "problematic fossil". For these and many other statements the author refers to his authorities,

unaware apparently of the additional knowledge acquired, and the consequent changes in nomenclature that have been made during the past twenty years.

There is a good general account of "Outdoor Work", but much of the "Indoor Work", such as the chemical analysis of rocks, other than blowpipe operations, must be left for the chemist. With regard to soils the author mentions that they "are best collected in artificial cuts or on the banks of streams, some 2 feet or so below the ordinary cultivated and altered surface"; but this will hardly apply, if the agricultural character of the soil is the object.

The subjects already mentioned occupy 236 pages; the remaining two-fifths of the volume (160 pages) are given to Practical Geology, to Water-supply, Building materials, Road-making, Earthworks of various kinds, including land reclamation and protection of sea-coasts, and to the uses of minerals for various purposes, including pigments. On these portions of his work the author writes with greater personal knowledge. While, however, he gives clear explanations of most of the phenomena, there are one or two illustrations, e.g. Figs. 84 and 87 in the section on water-supply, that are hardly intelligible or satisfactory. In the references to some of the building-stones the information quoted is not up to date: thus the Ketton and Ancaster stones, though formerly grouped with the Great Oolite, are now recognized as Inferior Oolite (Lincolnshire Limestone). The Aislaby Sandstone of East Yorkshire belongs, not to the Lias, but to the Lower Oolites (Lower Estuarine Series). A little more might have been said of the Scottish granites, those of Aberdeen and Peterhead not being described, although an analysis of the latter is given.

On the whole the work is rather overburdened with information that is of little practical value, but making allowance for the dates of publication of some of the works consulted the information has been gathered with evident pains and accuracy.

V.—Cambridge County Geographies.

THE Syndics of the Cambridge University Press are publishing, under the general editorship of Dr. F. H. H. Guillemard, a series of County Geographies suitable for general use as handbooks to the various counties, though primarily intended for use in schools. We have before us the volume on Cambridgeshire, by Professor T. McKenny Hughes and Mrs. Hughes (1909); Kent, by Mr. G. F. Bosworth (1909); Ayrshire, by Mr. John Foster (1910); and Fifeshire, by Mr. E. S. Valentine (1910).

The subjects are arranged in sequence, generally as follows, though naturally some of the topics are confined to particular counties: County and Shire, Physical Features, Rivers, Geology and Soil, Natural History, Coast (gains and losses), Climate and Rainfall, People and Dialect, Agriculture and Forestry, Industries and Manufactures, Minerals and Mines, Fishing, Shipping, History, Antiquities, Architecture, Roads, Railways, and Canals, Famous Inhabitants, Chief Towns and Villages.

The volumes are well printed and illustrated with views of scenery, buildings, celebrated individuals, etc., and they are accompanied by

physical and geological maps, colour-printed. The price is 1*s.* 6*d.* In size the volume on Kent occupies 146 pages, that on Cambridgeshire 271 pages. In the latter, as might be expected, we have not only a concise account of the Geology and Soil, leading up to the Natural History and the introduction of the plants and animals, but a much fuller account than in other volumes of the Antiquities from Palæolithic times and of the Architecture. Although the Soil is mentioned, but little is said about it except in reference to Forestry, and the relations of the geology to Agriculture are not dealt with. Among special cultivations in Cambridgeshire that of woad is interesting, the plant *Isatis tinctoria* being still grown for dyeing purposes, and an illustration is given of the Woad Mill at Parson's Drove, Wisbech.

The article on the Geology and Soil of Kent is not very satisfactory: the Thanet Sands are not "quite destitute of fossils", nor are the septaria in the London Clay of Sheppey "nodules of carbonate of lime and iron pyrites". The Oldhaven Beds mentioned on the map are not referred to in the text, the Thanet Beds are not mentioned in the legend to the map, while the Bracklesham Beds there noted do not occur in Kent.

Good accounts of the geology and the soils and of the mines and minerals are given in the geographies of Fifeshire and Ayrshire.

There is no question that the series is an attractive one, and will be widely appreciated.

VI. The Kelvingrove Museum, Glasgow.—Introductions to the study of minerals and of rocks, including Guides to the respective collections in the Museum, have been prepared by Mr. Peter Macnair, F.R.S.E., the Curator of the Natural History Collections (8vo; Glasgow, 1910 and 1911; price 3*d.* each). The Guide to the Mineral Collections is illustrated by a plan of the Gallery where the specimens are displayed, by various forms of crystals, and by a plate depicting pseudomorphs of Gaylussite, dredged from the Clyde at Cardross. Curiously enough this mineral is not mentioned in the index, although briefly described on p. 63. The Guide to the Rock Collections is more fully illustrated with plan, pictorial views of rocks in the field, photographs of rock-specimens, micro-sections of rocks, and diagrams of the crystalline forms of rock-making minerals. These handy Guides should prove very helpful to students.

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

February 2, 1911.—Sir Archibald Geikie, K.C.B., President, in the Chair.

The following communication was read:—

"On the Leaves of Calamites (*Calamocladus* Section)." H. Hamshaw Thomas, M.A., Curator of the Botanical Museum, Cambridge. Communicated by Professor A. C. Seward, F.R.S.

Most of the material investigated originally came from the Halifax

Hard Bed of the Lower Coal-measures. Most leaves were very small, being only 1–2 mm. long and ·8–1 mm. broad. They are falcate in shape, and were borne on slender twigs in alternating whorls of four. The structure of these slender twigs differs somewhat from that of the young Calamitean stems already described by Williamson and others, but it may be compared in some features with the structure of the young stems of some modern Equisetums.

The tissues of the small leaves show a concentric arrangement. In the centre there is a vascular bundle consisting of four or five small tracheides, surrounded by thin-walled elongated cells. The bundle is surrounded by a zone of cells with dense black contents, termed by Hick the melasmatic tissue, and is probably comparable with the bundle-sheath of the leaves of modern plants. The cells of the palisade-like assimilating tissue abut on to this; they have large spaces between them. The epidermis is thinner on the concave side of the leaf, and the stomata are situated on this face only. The latter are characterized by transversely striated guard-cells, similar to those seen in many species of modern Equisetums. These leafy twigs seem to be identical with the impression species *Calamocladus charæformis* (Sternb.); their structure seems to indicate that they grew in a pendulous manner. Specimens have been obtained showing variations in structure from the normal type.

Four other types of leaf have been discovered differing in size and in arrangement of tissues. In all of these there is a very conspicuous strand of sclerenchymatous fibres running up the adaxial side of the leaf, and forming a large part of its apex. These fibres become more conspicuous in the longer leaves. In some types the thin-walled (phlœm) tissue of the bundle is much reduced, or even absent. The melasmatic tissue also varies considerably in amount. Some of these longer leaves were probably identical with *C. grandis* (Sternb.); others with *C. equisetiformis* (Schloth.). They are characterized by a more compact structure, with smaller and fewer intercellular spaces.

The structure of the smaller leaves probably indicates that they grew in a moist situation, or where the atmosphere was humid. The larger leaves are more xeromorphic in character. The results obtained from this work indicate that the Calamites were truly microphyllous.

II.—Geological Society of London.

1. *March* 8, 1911.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The President announced that the Council had awarded the proceeds of the Daniel Pidgeon Fund for 1911 to Tressilian Charles Nicholas, B.A., Trinity College, Cambridge, who proposes to investigate the relations of the older rocks in the Lleyn Peninsula (Carnarvonshire).

The following communications were read:—

1. "Contributions to the Geology of Cyrenaica." By Professor J. W. Gregory and others.

(1) The Geology of Cyrenaica. By John Walter Gregory, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

According to the scanty evidence available in 1908 regarding Cyrenaica, which Hildebrand described in 1904 as "heute noch so gut wie unbekannt", the country might be interpreted as a fragment of a mountain-loop, an off-branch from the Atlas, or as a plateau of Miocene rocks.

In a journey across the country the author found that it was a plateau of Lower Kainozoic Limestones, which are classified as follows:—

Oligocene (Aquitanian)	Cyrene Limestones.	
Eocene	Slonta Limestones	= Priabonian.
	Derna Limestones	= Moqattam Series of Egypt.
	Apollonia Limestones	= Libyan Series of Egypt.

Some Miocene limestones occur in places on the plateau, and lying against its western foot.

These rocks are all limestones, containing very little clastic material. They must have been deposited in a clear sea, at depths ranging down to nearly 1,000 fathoms.

Intervals of shallow sea are indicated by some limestone conglomerates and a band of coral-reef limestone. The country was uplifted in later Miocene times, and was then part of a wide land which included Crete and occupied the site of the Ægean Sea. This land was broken up by great subsidences, which left Cyrenaica as a horst bounded by fault-scarps on the north and west. Eastwards the country sinks by a slight dip and a succession of faults, until the Miocene limestones, which occur on the plateau in Cyrenaica, are at sea-level on the coasts of Western Egypt. Cyrenaica may thus be regarded as part of the western limb of the geosyncline of Western Egypt.

The formation of the river-valleys probably began during a period of wetter climate than the present, but there is no evidence of any appreciable change in the climate or water supply since the date of the Greek and Roman colonization.

(2) Notes on the Kainozoic Mollusca. By Richard Bullen Newton, F.G.S.

The author determines a number of mollusca which are recognized as belonging to various members of the Kainozoic System, namely, post-Pliocene, Helvetian–Tortonian or Vindobonian, Aquitanian, Priabonian, and Lutetian. The most abundant of the post-Pliocene series is *Cerastoderma edule*, a species largely distributed over Northern Africa and the Mediterranean countries generally. Among the Helvetian–Tortonian forms are *Aleetryonia* cf. *virleti* and *Strombus* cf. *coronatus*—well known in North African rocks of this age, as well as in those of other Mediterranean regions.

The Aquitanian shells present a relationship to the 'Schioschichten' fauna of Northern Italy, and consist mainly of Pectinoid species, such as *Pecten vezzanensis*, *Equipecten* cf. *pasinii*, and *Spondylus cisalpinus*,

etc., associated with *Æquipecten zitteli*, *Æq. camaretensis*, and *Æq. scabrellus*, which are indicative of the later age—Burdigalian or Helvetian. This admixture of species, according to Dr. Oppenheim's memoir on the 'Schioschichten', is also known in the fauna of those rocks. Foraminiferal organisms (*Operculina*, etc.) occur in these beds, but no nummulites. *Lepidocyclina elephantina*, a good Aquitanian species, is found with *Oopecten rotundatus* from Birlibah.

The most characteristic of the Priabonian mollusca is *Pecten arcuatus*, a species occurring in Northern Italy, the Balearic Islands, Algeria, Tunis, the Balkan Peninsula, Armenia, etc. A new species of *Æquipecten* is described. Nummulites abound in these rocks.

An indeterminable ostreiform shell has been collected in the neighbourhood of Ain Sciahat, associated with the large *Nummulites gizehensis*—thus demonstrating that Lutetian rocks are present in Cyrenaica. So far as the mollusca are concerned, nothing older than Lutetian has been observed in this collection.

(3) Foraminifera, Ostracoda, and Parasitic Fungi from the Kainozoic Limestones of Cyrenaica. By Frederick Chapman, A.L.S., F.R.M.S.

This paper describes the Foraminifera, Ostracoda, and a parasitic fungus found in the limestones of Cyrenaica. The Foraminifera are mainly from the Middle Eocene; others belong to the Upper Eocene, and to the Aquitanian or Stampian. The most abundant Foraminifer is *Nummulites gizehensis*, which is represented in the Derna Limestones by its typical form, and is there associated with the typical form and a new variety of *N. curvispira*. At a higher horizon below Ain Sciahat and in the Slonta Downs is a nummulitic limestone containing *N. gizehensis*, var. *lyelli*.

Some limestones at Wadi Umzigga contain *Lepidocyclina elephantina*, and are referred to the Aquitanian or Stampian.

Further details are given of the structure of *Orthophragmina pratti*. A new species of *Loxoconcha* is described. The boring fungus *Palæachyla perforans* occurs perforating *Lepidocyclina*.

(4) The Fossil Echinoidea of Cyrenaica. By John Walter Gregory, D.Sc., F.R.S., F.G.S.

The Echinoidea collected in the journey across Cyrenaica are referred to ten species, of which two are new and one is a new variety. The echinoids come from four horizons: the oldest fauna belongs to the Middle Eocene; the Upper Eocene or Priabonian fauna is represented by an unusually early species of *Amphiope*, and by an *Echinolampas* which is widely distributed through the country and is referred to the Priabonian *E. chericherensis*, Gauth. Some echinoids from the Cyrene Limestones are of Aquitanian affinities, and others seen in the limestone east of Benghazi are Miocene. The affinities of *Hypsoclypeus hemisphericus* (Greg.) are considered. The echinoid faunas show that the Eocene rocks containing them were, as a whole, deposited in a sea of moderate depth. The Miocene strata were formed in comparatively shallow water.

(5) The Foraminiferal Limestones of Cyrenaica. By David Paterson MacDonald, M.A., B.Sc.

The microscopic examination of the limestones of Cyrenaica shows that they are all mainly composed of organic material, and are remarkably free from detrital material. The rocks were laid down under conditions of quiet sedimentation. Some of them have been partly dolomitized. The chalky limestones near the base of the series have been deposited at the greatest depth. The commonest organisms present are Foraminifera, Echinoderms including holothurian plates, Mollusca, and calcareous Algæ, which in some specimens form more than half of the whole rock. Some of the limestones are oolitic.

2. "On the Teeth of the genus *Ptychodus*, and their Distribution in the English Chalk." By George Edward Dibley, F.G.S.

This paper is an attempt to define the species of the fossil fish genus *Ptychodus*, and gives the result of the investigations pursued by the writer during the past twenty years among the extensive Chalk quarries in the Thames and Medway Valleys, West Kent, and the adjoining parts of Surrey, with reference to the zonal distribution of the genus.

The Medway Valley affords special facilities for such investigations, as there are numerous quarries worked there, from the *Micraster cor-anguinum* zone down to the Chalk Marl. In addition to material from the above-mentioned localities, material collected from the contents of the chief provincial museums, and also the specimens in the National Collections at the British Museum (Natural History) and the Museum of Practical Geology, Jermyn Street, have been studied in detail by the author, who has obtained no less than fifty associated sets of teeth from various localities.

Hitherto, our information as regards *Ptychodus* has been derived from associated sets of *Pt. decurrens* in place and isolated teeth of this and other species. The variation in teeth of one individual is often so marked, that when found separately they have given rise to the formation of new species. From evidence now brought together by the author for the first time, it can be proved that these teeth belong to already known species, and merely represent a phase in variation in the development of certain teeth of one species.

Special attention has been given to the extreme variation in *Pt. decurrens*, as well as in the equally variable species *Pt. polygyrus*, and one new species has been added.

A special feature is, that throughout the species a series of teeth extending from the centre to the exterior of the palate is figured, which also for the first time enables the student to form some idea of the variation exhibited by the separate rows, even in the teeth of the same individual, and indicates the care necessary in identifying species when dealing with solitary teeth.

III.—Mineralogical Society.

March 21, 1911.—Prof. W. J. Lewis, F.R.S., President, in the Chair.

Professor W. J. Lewis: On Mr. Solly's observation of Wiltshireite in 1903. Wiltshireite is identical with the mineral which Mr. Solly

exhibited and described before the Society November 17, 1903, and subsequently named rathite *a*, but of which no complete description has yet been published.—R. H. Solly: Two new minerals from the Binnenthal, Switzerland. Both are probably sulpharsenites of lead, being lead-grey in colour and giving a chocolate-coloured streak; one, which is rhombohedral-diplohedral, and has an angle 111 : 100 = 38° 18′, is probably isomorphous with trechmanite, while the other may be orthorhombic, the angle 100 : 110 being 58° 18′, but no measurable end faces were observed.—J. B. Scrivenor: Notes on Cassiterite in the Malay Peninsula. Cassiterite from a mine at Gopeng contains ilmenite and magnetite, and is attracted by the magnet; it also occurs mixed with tourmaline pseudomorphic after an hexagonal mineral, probably quartz. Arthur Russell: Notes on the occurrence of Dundasite in Derbyshire and Co. Galway, and of Bertrandite in Cornwall. Dundasite was discovered at Mill Close Mine, Wensley, Derbyshire, as snow-white spheres associated with greenockite, fluor, cerussite, calamine, etc., and at Clements lead mine, Carrowgarriff, near Maam, co. Galway, associated with allophane and cerussite, and bertrandite was found in platy crystals on old specimens of blende from Wheal Vor, Breage, Cornwall, and as trillings, measuring up to 4 mm. in length, on a specimen from Wheal Metal, Breage, Cornwall, which had been presented as albite to the British Museum in 1870; in the latter case the crystals were similar to those from Pisek, Bohemia, described by C. Vrba.—Dr. J. Drugman: On Quartz-twinning. The possible varieties of twinning of quartz were discussed, with special reference to the rhombohedron type, a specimen of which was exhibited.—T. V. Barker: Crystallographic Notes. Two new forms found on crystals of inosite confirm the hypohexagonal type of symmetry suggested by Fedorow. The rhombohedral modification of potassium nitrate, unlike sodium nitrate, does not arrange itself regularly when deposited on a cleavage piece of calcite: the crystals are very unstable, and rapidly pass into the ordinary orthorhombic form. A parallel growth of calcium chromate on the isomorphous mineral gypsum was obtained. New forms have been observed on urea nitrate which enabled the axial ratio $b : c$ for the first time to be calculated; the crystals have large birefringence, and, when grown in a drop, are nearly always twinned.

CORRESPONDENCE.

THE LAND-ICE HYPOTHESIS.

Sir,—In his letter in the last number of the Magazine (for April, p. 189), Mr. Deeley suggests that ice resting on frozen ground "would freeze to it and drag it along". I remember to have seen evidence of the rock on which *Boulder-clay* rests having been thus dragged along. The hill between Hastingfield and Barrington, near Cambridge, consists of Lower Chalk, or clunch, capped by Boulder-clay. Near the south crest of the hill, on the west side of the road, there is a large clunch pit, now little used, and when I last saw it the section was concealed. But a good many years ago the junction of the Boulder-clay and the

clunch was well exposed. The clay contained many glaciated pebbles of clunch, but the point of interest was that the clunch beneath the clay showed signs to the depth of several feet of having been dragged along, for it contained horizontal shearing planes, and was full of slickensides. The mechanics of this kind of action is not very obvious. It would not seem at first sight that this case was quite analogous to that supposed by Mr. Deeley, because it was not ice, but clay, which appeared in contact with the disturbed clunch.

Now though ice may be regarded as a highly viscous fluid, flowing, though slowly, like water, yet this condition cannot be predicated of Boulder-clay, much less so if the clay were frozen. But if it were not frozen, and was dragged along by a deep layer of ice that covered it, it can hardly be supposed that the ice communicated its own motion to the whole thickness of the plastic Boulder-clay, and through it to a considerable depth of solid clunch besides. Or was the clunch disturbed by the ice itself, in accordance with Mr. Deeley's suggestion, before any ground moraine had reached the locality?

The subject is worth investigation, and I would advise Cambridge geologists to keep a look out for the section being again exposed, or possibly to get it reopened for the purpose of examining it. A man with a pick and shovel could do it in an hour or so.

O. Fisher.

Graveley, Huntingdon.
April 19, 1911.

'FACETTED PEBBLES' AND 'DREIKANTER'.

Sir,—The reviewer of Messrs. Lake & Rastall's Text-Book of Geology (Geol. Mag., February, 1911, p. 85) states that the use of 'dreikanter' and 'zeugen' is pedantic and ill calculated to advance knowledge, and evidently considers that the expressions 'facetted pebbles' and 'tabular outliers' are equivalent, or "sufficient" as he calls it. Apart from the reviewer being wrong in both cases, the terms are recognized and used by geologists of many nationalities, and it is surely desirable in a textbook to employ standard words which the advancing student is likely to meet with elsewhere. If the suggestion of the reviewer were adopted and carried to its logical conclusion, the already considerable obstacle of language would be increased by each nation having its own set of scientific expressions.

A pebble may be facetted by glacial action, but there are characters which would often enable us to distinguish it from a dreikanter. The selective action of the wind-blast on softer parts of the rock may produce furrows, but these are not to be confused with glacial striæ.

A zeuge may take the form of a tabular outlier when it is formed of horizontal strata, and then only if there is a suitable arrangement of hard and soft beds. In country of massive, folded, or crystalline rocks the zeugen would not be tabular and 'outlier' a misnomer. I have just had the privilege of traversing some 800 miles of desert with no less an authority than Professor Walther, and in the course of